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SELDP Program Guide

Systems Engineering Leadership Development Program

SELDP provides systems engineers with an agency-wide perspective, hands-on systems engineering developmental assignments beyond what they can learn and experience at their home centers, advanced leadership skills development, and exposure to innovative government and industry-wide systems engineering concepts.

APPEL Program Management Office
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Image Credit: NASA

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OVERVIEW

Systems Engineering Leadership Development Program (SELDP)

NASA's vision and mission necessitate that its workforce is ready and able to lead the world in space exploration, scientific discovery, technology development, and managerial excellence. NASA leadership has identified systems engineering as a critical core competency in enabling current and future mission success. While many NASA centers have hands-on systems engineering development programs that provide targeted development and systems engineering training locally, NASA identified the need for an advanced, agency-wide program that competitively selects high-potential system engineers. As a result, the agency established the Systems Engineering Leadership Development Program (SELDP).

NASA's Office of the Chief Engineer (OCE) has robust program/project management and systems engineering training programs within the Academy of Program/Project & Systems Engineering Leadership (APPEL). With over 60 in-depth courses and its commitment to engineering excellence APPEL provides the alignment needed for employees to gain the technical training needed to successfully compete for SELDP.

SELDP provides systems engineers with an agency-wide perspective, hands-on systems engineering developmental assignments beyond what they can learn and experience at their home centers, advanced leadership skills development, and exposure to innovative government and industry-wide systems engineering concepts.

Since its inception, SELDP has achieved a consistent 90 percent success rate of individuals transitioning into more complex and difficult positions upon returning to their organizations after completion of the program.

ABOUT THE PROGRAM

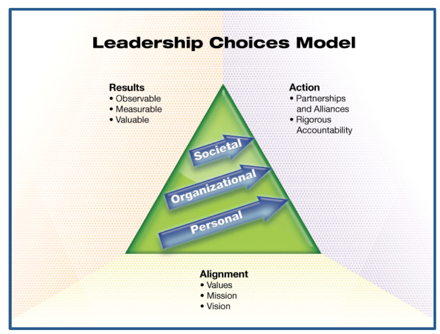
SELDP is a comprehensive program that provides leadership development, technical hands-on experience, leadership and technical training, benchmarking, mentoring, and coaching. The program's basis for design is founded in *The Art and Science of Systems Engineering* [**Attachment A: Full Version** | **Attachment B: Short Version**], the *NASA Systems Engineering Behavior Study* [**Attachment C**], and Behavior Competency Model. The behaviors exhibited by NASA's highly valued systems engineers fall into five broad themes with associated competencies and their observable behaviors: leadership, attitudes and attributes, communication, problem solving and systems thinking, and technical acumen. Strategic thinking and political savvy are two additional leadership skills identified by NASA's follow-on study of technical executives and are also covered in SELDP.

The design of SELDP is unique in that it incorporates "brain-friendly" learning techniques. Neuroscience has provided a wealth of information that has improved our understanding of how people learn, grow, and develop, and what factors enable or inhibit that learning. The SELDP design is continually adapting to ensure NASA's investment in learning works with the brain and not against it, resulting in greater retention and return on investment.

Learning Strategies

1. **Leadership Development:**
   Leadership development workshops are held to support the acquisition and refinement of critical leadership skills and abilities. The Leadership Choices Model forms the core of the leadership development strategy for SELDP.

   This model focuses on enabling participants to gain clarity about their own leadership goals and objectives and to clearly align them with the mission and the goals of NASA in a way that engages others. It then helps participants define the results they are committed to achieving and enables them to achieve these goals and build connections with others.



The Leadership Choices Model was initially developed by the Council for Excellence in Government Fellows program, but has been refined and updated to support NASA's needs.
Image Credit: NASA

2. **Assessments:**
   Assessment instruments are used to help participants gain a greater understanding of their strengths as areas for development. Unique to SELDP is a NASA Systems Engineering 360 Assessment Instrument developed from the systems engineering behavior study which helps participants understand how extensively and effectively they are applying these systems engineering behaviors.

3. **Leadership Training Workshops:**
   Training in SELDP focuses on leadership, attitudes and attributes, communication, political savvy, problem solving, and systems and strategic thinking. Depending on the unique needs of each class, training courses are provided as a part of each leadership workshop.

4. **Coaching:**
The participant's assessment results are used to form the basis for their leadership development strategy and coaching goals throughout the SELDP year. Certified professional coaches work with participants both during their developmental program to ensure successful transition back to their home centers and new responsibilities.

SELDP Learning Elements

1. **Developmental Assignments:**
Hands-on developmental assignments are a core requirement of SELDP that enables participants to gain greater understanding systems engineering, and expand the application of their systems engineering knowledge and skills. SELDP is different from other NASA developmental programs in that the participant does not identify their own developmental assignment. Assignment matching is done by SELDP Advocates using a multi-part process that ensures assignments meet the participant's developmental needs.

   Part I: Participants identify the competencies they need to develop to meet their next level of growth against the competencies available in the developmental assignments.

   Part II: Advocates use the results of the matching process as the first step in identifying the assignments that would best provide the experience needed by the participant and then assess participants against six additional dimensions—life cycle phase, mission, level (e.g. subsystem, instrument, system, vehicle), project level (e.g., task, project, element, program), leadership experience, and human or robotic—that would broaden and expand the participant's overall experience.

   Advocates ensure participants are placed in "stretch" assignments—areas where they have little or no previous experience and would expand their understanding of systems engineering and NASA's engineering culture. One participant noted, "I am still amazed that the assignment-matching group was able to identify a suitable assignment based on a short interview and application form. My assignment fully addressed the gaps in exposure to the rest of the agency and how large programs operate."

2. **Technical Training:**
Aside from Systems Engineering oriented problem solving assignments, Systems engineering and other classroom technical training is not a formal part of SELDP. Participants are expected to have the pre-requisite or equivalent courses upon entering SELDP. Little time is available for additional courses during the program year, but participants can sign up for additional APPEL courses or take advantage of center courses as needed for their assignment and as time permits.

3. **Center Visits and Outside Benchmarking:**
Benchmarking with other NASA centers and outside organizations to expand the participant's understanding and awareness of effective systems engineering and leadership is part of each leadership workshop.

4. Mentoring and Job Shadowing:

All participants are assigned a mentor to guide them in their developmental assignment. Participants are also encouraged to shadow other center leaders as time permits to learn more about their assignment centers and different leadership styles.

5. Jet Propulsion Laboratory Participants

Participants from the Jet Propulsion Laboratory (JPL), please refer to the following table for special information regarding your participation.

Element	From NASA to JPL	From JPL to NASA
Extended TDY & Program Travel	Funded by OCE	**Task order funding provided by JPL to OCE**
Salary and Benefits	Funded by Home Center	**Funded from JPL burden account. Cannot use funds provided by OCE**
Assignment Travel	Funded by OCE	**Can be funded by the assignment center through invitational travel orders or JPL burden account**
Travel Assignment	**Contact your Ethics Office for an our brief**	
Forms	**MOU for Temp. Assignments to JPL & NASA SELDP Ethics Statement**	

The NASA Jet Propulsion Laboratory is a Federally Funded Research and Development Center (FFRDC) operated for NASA by the California Institute of Technology (Caltech). Because of its special status, the JPL may have access to proprietary information to which NASA has no right of access. The JPL has privacy rights similar to those of any contractor. Because of the possible ethics issues that might arise in the course of an assignment of a NASA civil servant to the JPL, special arrangements have been made by the SELDP. These arrangements were created through the work of the NASA office of the General Counsel at NASA headquarters, the chief counsel of the NASA Management Office (NMO), and attorneys for Caltech.

While the nature of the ethical issues themselves is beyond the scope of this paragraph, it forms the basis of a special written agreement between NASA and Caltech and of a special ethics briefing that each SELDP participant who is detailed to the NASA JPL must obtain. Questions about specific ethical issues should be brought to an ethics officer (attorney) at any of the NASA centers, the JPL NMO, or the Office of the General Counsel at NASA Headquarters.

Specific procedures for SELDP participants assigned to the NASA JPL are outlined below. There are no special requirements, except for the normal SELDP program requirements, for JPL employees who are assigned by the SELDP to NASA centers.

NASA civil servants who are assigned to the JPL by the SELDP must prepare two documents in addition to the documentation that is required of all participants:

1. The SELDP participants assigned to JPL must complete the document entitled **Memorandum of Understanding (MOU) for Temporary Assignment at the Jet Propulsion Laboratory of NASA Employee Under NASAs Systems Engineering Leadership Development Program** [**Attachment D**]. Completion of this document entails filling in the blanks labeled in all-caps according to the specific details of the temporary assignment. Once completed and returned to the SELDP staff, the document will be signed by officials from NASA and Caltech. The participant does not sign this document.
2. The second document is entitled **NASA SELDP Ethics Statement** [**Attachment E**] and must be signed by the participant. The ethics statement is a promise by the participant to obtain an ethics briefing from an ethics officer at the participants home Center with participation from the Chief Counsel's office at the JPL NMO. Both documents should be returned to SELDP staff when complete.

Instructions for completing the form entitled "Memorandum of Understanding for Temporary Assignment at the Jet Propulsion Laboratory of NASA Employee Under NASA's Systems Engineering Leadership Development Program" are given below. The MOU form has been designed to allow you to "fill in the blanks" in a simple, intuitive manner. Questions that were asked by previous SELDP program participants were recorded as a set of Frequently Asked Questions (FAQs) and are listed below. The FAQs are expected to be updated each year as a result of new inputs.

Frequently Asked Questions regarding JPL:

1. Does *"LENGTH OF ASSIGNMENT"* include the time needed for travel and transportation of personal belongings and family members to and from the duty station?

    Yes. The length of assignment should be designed to encompass all SELDP program activities that are directly related to the new work assignment.

2. Does *"LOCATION WHERE THE NASA EMPLOYEE WILL WORK"* always mean "NASA JPL, Pasadena, CA?"

    No. In cases where the job assignment requires one or more duty stations instead of, or in addition to, the JPL, list each of the duty stations.

3. What level of detail is expected for *"NAME OF INTERNAL ORGANIZATION WITHIN JPL WHERE THE NASA EMPLOYEE WILL WORK AND A DETAILED DESCRIPTION OF THE NASA EMPLOYEES JOB ASSIGNMENT"*?

    You should write a paragraph that includes the name of the project, the name of the JPL project organization, the job title(s), and a reference to any known products.

4. What are the "important" parts of this MOU, or to what should I give the most attention?

    These questions will be answered during an ethics briefing that you will schedule with the ethics official from your home center. That ethics officer, in cooperation with the JPL NMO Chief Counsel, will explain the agreement and answer all your questions prior to your beginning the assignment at JPL.

5. Is there anyone that I need to contact when I arrive at JPL to begin the assignment?
   In addition to meeting with the JPL SELDP Advocate, you should visit the NMO Chief Counsel's office and meet the staff. You should ask the staff how to obtain your copy of the rules and policies that govern the internal operations and management of Caltech/JPL that is referenced in the MOU.
6. What if I have other questions?
   Feel free to contact the **SELDP staff** with any questions.

2016-2017 Selection Schedule *(*Dates are subject to change)*

Month	Program Activities
January 2016	Release SELDP Program Call (See Call for Nominations Letter for current schedule)
April 2016	Nominations and Assignments Due
June 2016	Candidate Interviews and Participant Selection

Program Year Schedule *(*Dates are subject to change)*

Month	Program Activities
August 2016	Orientation Workshop – Coaching Begins
August 2016	Developmental Assignments Can Begin (6-9 months, over 18 months)
October 2016	Leading for Results
January 2017	Leading Through Power Dialogue and Collaboration
March 2017	Leading Through Powerful Communication
May 2017	Leading in a Dynamic Environment
July 2017	Leading With Presence
September 2017	Using Your Leadership Voice

SELDP Funding

Centers are responsible for funding:

- Participant’s salary
- Travel to/from the interview
- Travel to/from orientation
- Training and associated travel that is not part of SELDP workshops
- Additional trips home, above the allowed quarterly trip
- Project travel required for participants assigned to their center

The Office of the Chief Engineer funds:

All other program travel and training for participants, including NASA employees assigned to JPL. Not all reimbursements allowed by the Federal Travel Regulations (FTR) are covered by SELDP. (Note: Items covered in the FTR that are not reimbursable by SELDP include commuting mileage and costs, maid services, dry cleaning and laundry, and rental cars.)

Jet Propulsion Laboratory Participants:

JPL is responsible for funding all costs associated with their employees’ participation in the program as noted above with the exception of employee project travel required for participants assigned to their center.

HOW TO PARTICIPATE

SELDP participants are identified using a rigorous nomination and selection process. Each year, NASA's Chief Engineer distributes a call for nominations to all NASA centers. Center leadership identifies strong candidates for the program and submits the appropriate nomination forms, which are reviewed and processed by the SELDP selection committee.

NASA and the centers gain the greatest return on investment when nominees are selected as part of the center's strategic mid- to long-term investment. This investment is only successful when a center's systems engineering needs are met, which means that upon return, the participant is placed in a position where the learning experience they gained in the program is quickly applied to meeting essential center needs.

Candidate Eligibility

SELDP candidate criteria:

- Full–time, permanent GS-13 to GS-15 NASA employee or a senior systems engineer at JPL.
- Bachelor's degree in engineering or Specialties of Aerospace Technology (AST) equivalent.
- Be willing and available to leave their home center and take on an assignment at another NASA center for 6 to 9 months.

Experience needed to be successful in SELDP:

- The participant is an employee who understands and has exposure to a breadth of systems engineering (SE) competencies as **defined by APPEL**.
- The participant has experience applying SE principles on one or more projects or programs.
- The participant is at least APPEL Proficiency Level II.
- The participant has taken one of more of the recommended SE APPEL Training including: **Foundations of Aerospace at NASA**, **Project Management and Systems Engineering**, and **Fundamentals of Systems Engineering**, or equivalent courses.

Additional candidate considerations:

Nominees for SELDP must be individuals who have the experience and opportunity to take advantage of a developmental assignment away from their home center for 6 to 9 months. Family obligations and current assignment requirements and timing should be taken into account to also determine the optimal window of participation in this program. Participants in SELDP engage in very demanding assignments and development activities. It is impossible for an individual to be successful in this program unless they are released completely from their home center obligations.

There is a significant amount of preparation necessary for the participants to transition to their developmental assignments. Home supervisors can best ensure project continuity and support participant assignment transition by arranging early for the transfer of responsibilities from these participants to the individuals who will be acting for them while they are away. A minimum of two weeks is recommended.

Candidate Nomination

Before identifying candidates, centers should consider the systems engineering knowledge, skills, and abilities they need to successfully run their programs in the next 18 to 24 months. Center engineering leadership is encouraged to consider the following questions when selecting nominees for SELDP:

- Why are you nominating this person for SELDP at this time in their career?
- In your opinion, why is SELDP the best option for the candidate?
- What specific learning gaps does SELDP fill for this person?
- What unique learning and experience will this person gain from SELDP that will help them do a better job?
- What systems engineering challenges will your center be facing in the next 18 to 24 months?
- What knowledge, skill, and/or experience does this person need to bring back that will help support these challenges?

The competitive process ensures that:

- Participants have demonstrated the leadership behaviors and aptitude that NASA identifies as critical to becoming an expert systems engineer, along with demonstrated technical/discipline capabilities
- The most qualified nominees are selected for this opportunity when the learning will have the greatest impact on the employee and provide the greatest value to NASA.
- Participants have the experience and attitude to be successful in the program.
- There is an appropriate assignment available to meet the participant's needs.
- Participants have top-level center engineering leadership support needed to be successful in the program, and
- Participants are placed in a position that quickly applies their SELDP learning when they return their home center to ensure maximum transfer of learning and return on investment.

Agency Selection Process

Center engineering directors or their designees and members of the Safety and Mission Assurance community serve as the selection panel for SELDP participants. Participants are chosen using a four-part competitive selection process:

1. Center competition, nomination, and endorsement by center engineering leadership and the center director.
2. Rating and ranking of applications by the SELDP selection panel based on specific criteria to ensure applicant has met the program requirements and has the background to be successful in SELDP.
3. Selection panel interview of qualified applicants ensure applicant has the demonstrated leadership behaviors and aptitudes of highly successful systems engineers.
4. Advocate matching of selected applicants to available developmental assignments.

Application Materials

Below are the detailed program requirements, call for participants, nomination forms, and other pertinent materials to nominate candidates for SELDP. The call and application materials are scheduled for release every other year.

Program Requirements

- Provide a comprehensive development program that provides for leadership and technical development, training and benchmarking, coaching, and mentoring.
- Provide opportunities for employees from across NASA to participate in a year-long developmental program. Participants are to be GS-13 or GS-15 engineers or AST equivalents. Participants from the Jet Propulsion Laboratory (JPL) must be Senior Systems Engineers.
- Provide a process that ensures the selection of high potential participants who have proven technical/discipline capability, and who have demonstrated key leadership capabilities and behaviors. Select individuals who are nominated by their Center Director and Center Engineering Director and who are expected to lead higher-level or more complex efforts in the next 18 to 24 months versus employees who are merely available. The SELDP competitive process ensures that:
    - Participants have demonstrated the leadership behaviors and aptitude that NASA identifies as critical to becoming an expert Systems Engineer (see **Systems Engineering Leadership Behavior Study** [**Attachment F**], along with demonstrated technical/discipline capabilities (see **APPEL Systems Engineering Technical/Discipline Competency Model** and **NASA Systems Engineering Training**).
    - The most qualified nominees are selected for this opportunity at the right time in their career, when this learning will have the greatest impact.
    - Participants have the experience and attitude to be successful in the program.
    - There is an appropriate assignment available to meet the participants' developmental needs.
    - Participants have the top-level Center engineering leadership support needed to be successful in the program, and to be placed in a position that quickly applies this learning upon return to the Center to ensure maximum transfer of learning and return on investment.
- Ensure that the program offered provides an integrated learning approach that allows participants to:
    - Gain hands-on developmental experience outside the participant's home Center that will broaden and improve their discipline knowledge, skills and abilities to lead complex Agency-wide programs and projects;
    - Obtain development and coaching needed to enhance key leadership skills and abilities and improve or adopt behaviors that NASA has identified as critical to becoming a highly effective Systems Engineer;
    - Obtain critical thinking, systems thinking, judgment, and decision making skills, through training and case studies necessary to make system trade-offs to optimize program and project effectiveness;
    - Create an Agency-wide learning community and network of Systems Engineers across NASA;
    - Obtain mentoring by top NASA systems engineers both at their home Centers and at their developmental assignments;
    - Improve leadership effectiveness through coaching and feedback;
    - Provide interactions and learning from key NASA and outside leaders;
    - Provide technical training before the start of assignments that are critical to success.
    - Benchmark with other NASA Centers and world-class outside Systems Engineering organizations.

- Ensure Centers have for individual development plans (IDP) for each participant. Identified experienced Center systems engineering advocates will perform gap analysis for each participant and match participants with the appropriate developmental assignment.

Call Letter:

- **Current Call for Participants Letter** [**Attachment G**] **–** Letter from NASA's Chief Engineer calling for SELDP participant nominations from across the agency.

Nomination Forms:

- **SELDP Nomination Form –** Log into the **NASA Electronic Forms Portal**, search for form 1781 and complete.
- **Form NF 1781A: SELDP Assignment Summary –** To be completed by the SELDP advocate. Log into the **NASA Electronic Forms Portal**, search for form 1781A and complete.
- **Form NF 1781B: SELDP Participant Summary –** Checklist for the SELDP candidate and to be filled out by the candidate and supervisor. Log into the **NASA Electronic Forms Portal**, search for form 1781A and complete.

Nomination Supplements:

- **Current Selection Criteria** [**Attachment H**] **–** Identifies the criteria used by the SELDP Selection Panel to rate and rank nominee applications.
- **Current SELDP Supervisor and Engineering Director's Application Checklist** [**Attachment I**] – Identifies items for consideration throughout the participant nomination process to determine the best candidates for SELDP. This checklist should not be included in the final application package submitted to NASA Headquarters.
- **Current Engineering Director and Center Director Nomination and Endorsement Template/Example** [**Attachment J**] – Sample Word document for participant endorsement and nomination. Please complete and return with nomination materials.

Please check with your Center Training Office for center-specific application requirements and schedule.

LEARNING AND SUPPORT NETWORK

SELDP participants benefit from comprehensive training and development aligned with a sophisticated learning and support network. This model is essential to NASA mission success and return on investment for the program and its class.

System Map Interrelationships

POSITIONS	RESPONSIBILITIES & RELATIONSHIPS
Office of the Chief Engineer/SELDP Program Management	Defines learning needs, establishes program goals, and coordinates with the SELDP Board—the Engineering Management Board (EMB). Designs, delivers and assess program.
Engineering Management Board	Provides leadership guidance, and identifies and endorses high-potential candidates.
Center Directors	Coordinates with the EMB on the goals and strategy for using SELDP to develop Center employees.
Home Supervisors and Mentors	Identifies potential candidates, provides input into their developmental assessment, and defines how employee will contribute upon return.
Advocates	Appointed by the EMB. Coordinates candidate identification, mentor participants, and provides status updates to EMB.
Center Training Coordinators	Coordinates local candidate selection with all parts of the system.
Participants	Responsible for learning, performing assignments, and communicating their status with home center. Accountable for returning to their centers with abilities and readiness to perform at the next highest level.
Assignment Supervisors and Mentors	Identifies potential developmental assignments. Responsible for developing the participants while on assignment.
Consultants and Trainers	Responsible for training and developing participants and providing advice on recommended program changes.
Coaches	Provides one-on-one and group coaching to participants.
Outside NASA	Shares program information and findings with outside organizations.

Office of the Chief Engineer (OCE) SELDP Program Management

NAME	TITLE
Ralph Roe	NASA Chief Engineer
Dawn Schaible	NASA Deputy Chief Engineer, SELDP Sponsor
Roger Forsgren	Director of APPEL, SELDP Program Director
Jon Holladay	NESC Systems Engineering Tech Fellow
Kevin Magee	SELDP Program Manager

RESOURCES

SELDP draws upon a number of reports, studies, and models to develop program participants, and provides a variety of additional learning content and resources.

Systems Engineering Competencies

Competencies are the combination of knowledge, skills, and abilities that contribute to individual and organizational performance. The APPEL developmental framework is based on a rigorous set of competencies that practitioners should have in order to perform their jobs. These competencies define the breadth and scope of the discipline and facilitate personal development and assessment of individual knowledge and capabilities.

These competencies were derived from many sources including extensive interviews with several hundred highly successful project managers and system engineers at NASA. The resulting competencies were vetted with both internal and external organizations to ensure completeness and accuracy. Since the competencies form the foundation of the development program, they are under configuration control and are reviewed and updated as appropriate.

A key step for the NASA's technical practitioners is to understand the requirements of their roles and the related competencies. APPEL seeks to help practitioners refine their competencies in order to reach the highest level of performance. The NASA Project Management and Systems Engineering Competency Framework consist of five project management competency areas, three systems engineering competency areas, and five competency areas common to both the project management and systems engineering communities. Performance-level descriptions for each competency have been created to guide the overall development of individuals within the program/project and engineering disciplines. **Visit the APPEL PM&SE Development Gateway to view the competency framework.**

To further support individuals as they work to identify their appropriate development activities, APPEL provides the Course Competency Matrix in the **APPEL Program Catalog**. This catalog can be used as a guide in the selection of courses based on competency development and individual learning needs. In addition to competencies, the matrix includes other course elements that may be of interest to individuals considering attending a particular course. The table represents a snapshot of all APPEL courses including the course duration, audience, and goal for each APPEL course.

Studies and Suggested Readings

- **Executive Leadership at NASA: A Behavioral Framework** [**Attachment C**]
  Published in June 2010, this study was conducted to identify the behaviors and attributes exhibited by the agency's most successful executives.

- **NASA Systems Engineering Behavior Study** [**Attachment F**]
  Published in October 2008, this study was conducted to identify the characteristics or behaviors frequently observed in highly regarded systems engineers at NASA.

- **Executive Behavior Validation Study** [**Attachment K**]
  Published in December 2011, this large-scale study was conducted to quantitatively analyze the behavioral framework developed in the *Executive Leadership at NASA: A Behavioral Framework* publication.

- **Recommended Reading List**
  SELDP participants may be interested in these suggested readings in systems engineering, systems thinking, leadership, project management, and related disciplines.

SE Curriculum

The emphasis of the SELDP is on hands-on technical assignments at NASA field centers with various programs and projects. Prior to and during participation in the program, participants are expected to conduct objective analysis of their core systems engineering knowledge, understanding, and practice. The APPEL SELDP coordinator assists participants with this assessment. Should a deficiency be identified in any major systems engineering (SE) concept, processes, policy etc., it is recommended that the participants obtain the necessary training through APPEL or another credible provider.

The APPEL Systems Engineering Curriculum is based on a development model or framework and defined SE competencies. Course offering dates and locations are available on the APPEL Master Schedule.

Recommended SELDP Prerequisite Courses:

- **Foundations of Aerospace at NASA***
  Addresses the meaning of working at NASA and the principles of technical excellence. Focuses on providing participants with a big picture overview of NASA, its history, mission, its Governance model and Agency operations. Focuses on communication and team participation skills.

- **Project Management and Systems Engineering***
  Enhances proficiency in applying PM and SE processes/practices over the project life cycle. Focuses on defining and implementing system projects and provides valuable insight for managing and leading project and technical teams.

- **Fundamentals of Systems Engineering***
  Introduces methods and techniques for a structured systems development process that proceeds from requirements to concept to production to operation, based on NPR 7123.1B and NPR 7120.5D. Focuses on the interfaces between the people, processes, and products. Equips teams with knowledge necessary to realize successful solutions.

**Attendance In at least one prerequisite course required prior to applying for SELDP.*

Recommended SELDP Courses:

- **Advanced Project Management and Advanced Systems Engineering****
  Focuses on advanced concepts of Project Management and Systems Engineering and their integration in the management of all phases and facets of the project life cycle. Uses case studies to examine topics such as system architecting, performance, risk, cost, schedule, reliability and operability, stakeholder management and acquisition strategies. Provides knowledge to realize project solutions and leverage Project Management and Systems Engineering roles and responsibilities defined in NPR 7120.5D and NPR 7123.1A.

***Attendance recommended prior to or during SELDP.*

Additional APPEL SE Courses:

- **Decision Analysis (DA)**
  Designed to provide the tools necessary to improve the quality of a factually based decision-making process for resolving technical issues at NASA.

- **Developing and Implementing a Systems Engineering Management Plan (SEMP)**
  Introduces the processes that support planning, development and execution of a Systems Engineering Management Plan (SEMP). Includes how Systems Engineering deliverables are planned and managed. Participants experience Systems Engineering technical reviews and appreciate the value of these ‘gates’.

- **Earth, Moon, and Mars (EMM)**
  Introduces the remarkable discoveries of how these planetary bodies formed and the kinds of geologic processes that continue to operate on them today. Participants will also learn of the unique geologic challenges that the Moon and Mars pose to future exploration.

- **Lifecycle Processes and Systems Engineering (LPSE)**
  Introduces Systems Engineering processes, NASA life-cycle phases, key technical reviews, and Systems Engineering management techniques. Helps participants realize the value of well-established Systems Engineering processes and deliverables.

- **Manned Mission and System Design Lab (MMSD)**
  Provides experience of conceptualizing and designing space missions to Mars or the Moon. Provides an integrated view of space mission design and operations.

- **Requirements Development and Management (REQ)**
  Provides a foundation for the development and management of a project’s product requirements. Includes requirement best practices that help project teams develop a product that delivers what is needed — on-time and within cost and expected quality.

- **Seven Axioms of Good Engineering (SAGE) A Case Study Course: Learning From Failure**
  Promotes good engineering design and PM decision making via case studies and discussion. Promotes critical thinking and improves decision making among engineers, technologists, PMs, and scientists.

- **Space System Verification and Validation (SSVV)**
  Demonstrates the processes, information, and tools necessary to implement a credible verification, integration and test program. Provides exposure to NASA and Dept. of Defense (DoD) standards, lessons learned, tools, and experiences in validation and verification.

The following required leadership and communications courses are provided to participants at leadership workshops during their SELDP year. These courses are modified or changed based on an annual analysis of key leadership skills needed at NASA:

- Building Partnerships through Systems Thinking
- Crucial Conversations
- Leading Change through Effective Facilitation
- Leading Others through Coaching
- Business Acumen and Political Savvy
- Leading with the Brain in Mind
- Building a Reentry Strategy
- Driving Results

  The SELDP baseline set may be modified as influenced by strategic activities of the Agency or newly established best practices.

Videos and Images

Watch videos of practitioners and former SELDP graduates sharing their insights about systems engineering and view images from each class.

View the Systems Engineering playlist on APPEL's YouTube channel.
View images from each class on APPEL's Flickr page.
Read stories about SELDP events and participants.

ATTACHMENTS

Attachment A: The Art & Science of Systems Engineering (Full)

Attachment B: The Art & Science of Systems Engineering (Short)

Attachment C: Executive Leadership @ NASA: A Behavioral Framework

Attachment D: Memorandum of Understanding for Temporary Assignment at the Jet Propulsion Laboratory (JPL) of NASA Employee Under NASA's SELDP

Attachment E: NASA SELDP Ethics Statement

Attachment F: Systems Engineering Leadership Behavior Study

Attachment G: Call Letter

Attachment H: Selection Criteria

Attachment I: Current SELDP Supervisor and Engineering Directors Application Checklist

Attachment J: Engineering and Center Director Endorsement Letter

Attachment K: Executive Behavior Validation Study

The Art and Science of Systems Engineering*

Michael Ryschkewitsch, *National Aeronautics and Space Administration*
Dawn Schaible, *National Aeronautics and Space Administration*
Wiley Larson, *Stevens Institute of Technology*

The Scope of Systems Engineering

The Personal Characteristics of Good Systems Engineer

Realities of Complex System Design

Processes for Systems Engineers

The Best Preparation

Summary

This work culminates years of experience in systems engineering and focused discussions among NASA leadership, systems engineers, and systems engineering trainers across the Agency. One consistent theme in these experiences and discussions is that NASA uses many definitions and descriptions of systems engineering. We use the terms and job titles of chief engineer, mission systems engineer, systems engineering and integration manager, system architect, vehicle integration, and so on for various pieces of the complete systems engineering function. We need to agree on a common understanding of systems engineering. In addition, no matter how we divide the roles and responsibilities among people, we must ensure that those roles and responsibilities are clear and executed as a functional whole. **Our objectives are to provide a clear definition of systems engineering, describe the highly-effective behavioral characteristics of our best systems engineers and make explicit the expectations of systems engineers at NASA.**

Systems engineering is both an art and a science. We can compare systems engineering to an orchestra and its ability to perform a symphony. Most people understand what music is, but not everyone can play an instrument. Each instrument requires a different level of expertise and skill. Some musicians spend their entire careers mastering a single instrument, which is good because each one needs to be played well. But sophisticated music involves many different instruments played in unison. Depending on how well they come together, they may produce beautiful music or a terrible cacophony.

* Systems engineering is a critical core competency for successful NASA missions. This monograph summarizes the collective wisdom of some of NASA's best technical minds on the subject. So here the word "we" represents all contributors to this effort: Michael Bay, Bill Gerstenmaier, Mike Griffin, Jack Knight, Wiley Larson, Ken Ledbetter, Gentry Lee, Michael Menzel, Brian Muirhead, John Muratore, Bob Ryan, Mike Ryschkewitsch, Dawn Schaible, Chris Scolese, and Chris Williams. Among them, they have more than 390 years—almost four centuries—of experience in aerospace and systems engineering.

We can think of a symphony as a system. The musicians apply the science of music: they follow the process of translating notes on a page to play their instruments. But an orchestra conductor, a maestro, must lead them to connect the process of playing to the art of creating great music. Maestros do a lot more than just keep time! They:

- Know and understand music—such matters as pitch, rhythm, dynamics, and sonic qualities—as well as the capabilities of various instruments and musicians
- Are necessary once the orchestra reaches a certain size and complexity
- Have typically mastered one or more musical instruments
- May be composers
- Select and shape the music that an orchestra plays
- Interpret a composer's music in light of the audience
- Strive to maintain the integrity of the composer's intentions
- Organize and lead the musicians
- Are responsible for the success of the performance

The systems engineer is like the maestro, who knows what the music should sound like (the look and function of a design) and has the skills to lead a team in achieving the desired sound (meeting the system requirements). Systems engineers:

- Understand the fundamentals of mathematics, physics, and other pertinent sciences, as well as the capabilities of various people and disciplines
- Have mastered a technical discipline and learned multiple disciplines
- Must understand the end game and overall objectives of the endeavor
- Create a vision and approach for attaining the objectives
- May be architects or designers
- Select and shape the technical issues to be addressed by multidisciplinary teams
- Must often interpret and communicate objectives, requirements, system architecture, and design
- Are responsible for the design's technical integrity
- Organize and lead multidisciplinary teams
- Are responsible for the successful delivery of a complex product or service

The similarities between maestros and systems engineers are useful in describing the latters' desired behavioral characteristics and capabilities.

> A great systems engineer completely understands and applies the art of **leadership** and has the experience and scar tissue from trying to **earn** the badge of **leader** from his or her team.
>
> *Harold Bell*
> *NASA Headquarters*

Systems engineering is the art and science of developing an operable system that meets requirements within imposed constraints. This definition is independent of scale, but our discussion here focuses on developing complex systems, such as aircraft, spacecraft, power plants, and computer networks.

Systems engineering is holistic and integrative. It incorporates and balances the contributions of structural, mechanical, electrical, software, systems safety, and power engineers, plus many other, to produce a coherent whole. Systems engineering is about tradeoffs and compromises, about generalists rather than specialists.

Systems engineering is not only about the details of requirements and interfaces among subsystems. Such details are important, of course, in the same way that accurate accounting is important to an organization's chief financial officer. But accurate accounting does not distinguish between a good financial plan and a bad one, nor help to make a bad one better. Similarly, accurate control of interfaces and requirements is necessary to good systems engineering, but no amount of care in such matters can make a poor design concept better. **Systems engineering is first and foremost about getting the right design**—and then about maintaining and enhancing its technical integrity, as well as managing complexity with good processes to get the design right. We define interfaces in a system design to minimize unintended interactions and simplify development and operations—and then we document and control the design. Neither the world's greatest design, poorly implemented—nor a poor design, brilliantly implemented—is worth having.

The principles of systems engineering apply at all levels. For example, engineers who are developing an avionics system must practice creative design and interface definition to achieve their goals. Similar activities are essential to the architecture, design, and development of elements and subsystems across the broad spectrum of NASA developments. But for the remainder of this discussion, we use the term "systems engineering" in the context of complex, multidisciplinary system definition, development, and operation.

In his 2007 presentation, "Systems Engineering and the 'Two Cultures' of Engineering," Mike Griffin describes how the complexities of today's aerospace systems and the ways they fail have led to branching within the industry. For our purpose, we divide systems engineering into technical leadership and its ally, systems management.

- Technical leadership focuses on a system's technical design and technical integrity throughout its lifecycle
- Systems management focuses on managing the complexity associated with having many technical disciplines, multiple organizations, and hundreds or thousands of people engaged in a highly technical activity

> Once a credible design and architecture are established, the systems engineer's job is to maintain technical integrity throughout the complex system's very rigorous and challenging lifecycle phases.
>
> *Robert Ryan, Marshall Space Flight Center*

Technical leadership, the *art* of systems engineering, balances broad technical domain knowledge, engineering instinct, problem solving, creativity, leadership, and communication to develop new missions and systems. It is the system's complexity, and severity of its constraints—not just its size—that drives the need for systems engineering.

NASA systems are often large and complex, so they require systems engineers to work in teams and with technical and other professional experts to maintain and enhance the system's technical integrity. The creativity and knowledge of all of the people involved must be brought to bear to achieve success. Thus leadership and communications skills are often as important as technical acumen and creativity. This part of systems engineering is about doing the job right.

For large complex systems, there are literally millions of ways to fail to meet objectives, even after we have defined the "right system." It is crucial to work all the details completely and consistently and ensure that the designs and technical activities of all the people and organizations remain coordinated—art is not enough.

Systems management is the *science* of systems engineering. Its focus is on rigorously and efficiently managing the development and operation of complex systems. Effective systems management requires applying a systematic, disciplined engineering approach that is quantifiable, recursive, repeatable, and demonstrable. Here the emphasis is on organizational skills, processes, and persistence. Process definition and control are essential to effective, efficient, and consistent implementation. They demand a clear understanding and communication of the objectives, and vigilance in making sure that all tasks directly support the objectives.

> Systems management provides a framework for problem solving...creative problem solving for complex systems.
>
> *Dinesh Verma,*
> *Stevens Institute of Technology*
>
> One of the biggest challenges for a systems engineer of a large complex project is to "bring order from chaos."
>
> *Chris Hardcastle,*
> *Systems Engineering and Integration Manager, NASA's Constellation Program,*
> *Johnson Space Center*

Systems management applies to developing, operating, and maintaining integrated systems throughout a project or program's lifecycle, which may extend for decades. Since the lifecycle may exceed the memory of the individuals involved in the development, it is critical to document the essential information.

To succeed, we must blend technical leadership and systems management into complete systems engineering. Anything less results in systems not worth having or that fail to function or perform.

The Scope of Systems Engineering

Since the late 1980's, many aerospace-related government and industry organizations have moved from a hard-core, technical leadership culture (the art) to one of systems management (the science). History has shown that many projects dominated by only one of these cultures suffer significant ill consequences. Organizations that focus mainly on systems management often create products that fail to meet stakeholder objectives or are not cost effective. The process often becomes an end unto itself, and we experience "process paralysis." Organizations that focus solely on technical issues often create products or services that are inoperable, or suffer from lack of coordination and become too expensive or belated to be useful.

To achieve mission success, we must identify and develop systems engineers that are highly competent in both technical leadership and systems management.

That is why we focus on the complete systems engineer, who embodies the art **and** science of systems engineering across all phases of aerospace missions—a type reflected in Figure 1. In any project, it is critical that systems engineering be performed well during all lifecycle phases. The scope of systems engineering and the associated roles and responsibilities of a systems engineer on a project are often negotiated by the project manager and the systems engineer. The scope of systems engineering and the activities for which the systems engineer is both responsible and accountable should be understood and documented early in the project.

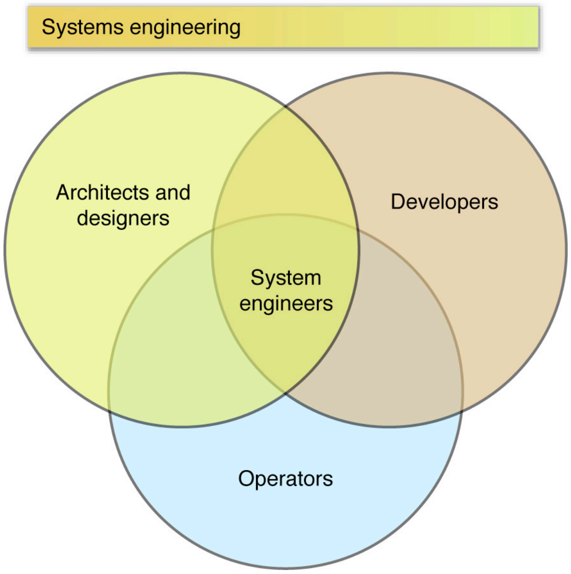


Figure 1. . **The Scope of Systems Engineering.** Systems engineers often focus on one lifecycle phase like architecture and design versus development or operations, but good systems engineers have knowledge of and experience in all phases.

Here we describe the characteristics, some innate and others that we can develop, that enable select people to "systems engineer" complex aerospace missions and systems—to design, develop, and operate them. Then, we focus on how to further develop NASA's systems engineers to help them deal better with the complexities of sophisticated missions and systems.

The Personal Characteristics of Good Systems Engineers

Figure 2 depicts the personal behavioral characteristics of effective systems engineers.

Intellectual curiosity. Perhaps the most important personal characteristic of successful systems engineers is *intellectual curiosity*. People who prefer boundaries around their work to be comfortable, know what they know, and enjoy a focused domain may want to consider another occupation. Systems engineers continually try to understand the what, why, and how of their jobs, as well as other disciplines and situations that other people face. They are always encountering new technologies, ideas, and challenges, so they must feel comfortable with perpetual learning.

> People who have "systems engineer" in their title, regardless of the modifiers—project, program, flight system, and so on—are responsible for everything.
>
> *Gentry Lee,*
> *Jet Propulsion Laboratory*

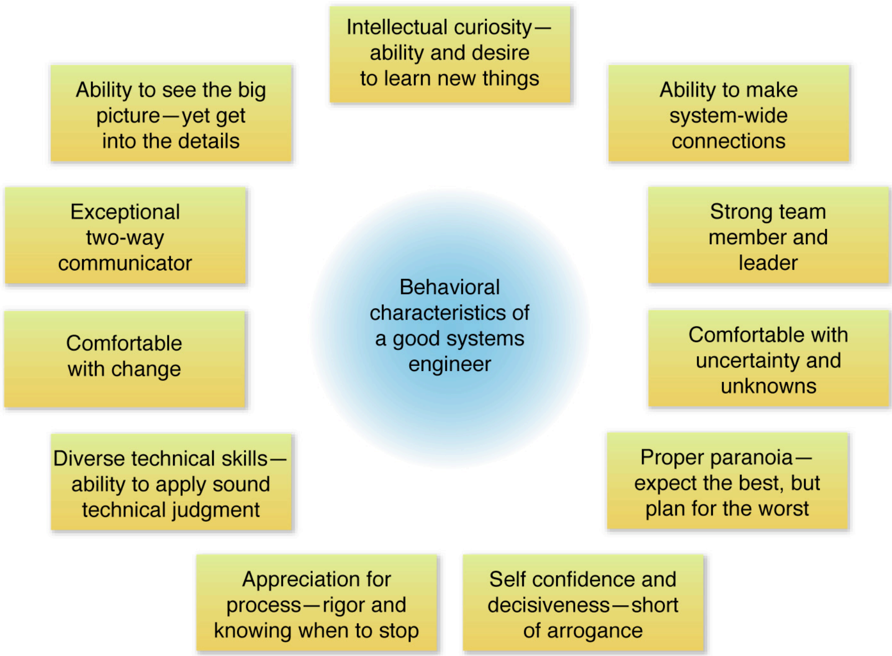


Figure 2. . **Characteristics of a Good Systems Engineer.** The characteristics are shown in decreasing priority from top to bottom. Some of them are innate, whereas others can be learned and honed.

Ability to see the big picture. Good systems engineers maintain a *big-picture perspective*. They understand that their role, though always significant, changes throughout a project's lifecycle. At any point in the lifecycle the systems engineer must be fully cognizant of what has been done, what is necessary, and what remains to be done. Each phase has a different emphasis:

- Concept—mission and systems architecture, design, concept of operations, and trade studies
- Development—maintaining technical integrity throughout all lifecycle phases: preliminary design review, critical design review, verification, validation, and launch
- Operations—making sure that the project meets mission requirements and maintains technical integrity

Systems engineers pay particular attention to verification and validation. Verification answers the question: "Did we build our system right?" If we are successful, it proves our product meets the requirements. We emphasize the hard-earned lesson, "Test like you fly, fly like you test." Validation, on the other hand, answers the question: "Did we build the right system?" If we are successful, the system does what it is supposed to do, which often goes well beyond just meeting requirements!

Good systems engineers are able to "translate" for scientists, developers, operators, and other stakeholders. For example, "Discover and understand the relationship between newborn stars and cores of molecular clouds," is meaningful to a scientist. But developers and operators would better understand and use this version: "Observe 1,000 stars over two years, with a repeat cycle of once every five months, using each of the four payload instruments." The systems engineer that knows the project's objectives, helps determine how to meet them, and maintains the system's technical integrity throughout its lifecycle has a good chance of succeeding. A corollary is to check everyone's understanding of each other to make sure the team truly IS on the same page.

Ability to make system-wide connections. First-rate systems engineers understand the *connections* among all elements of a mission or system. They must often help individuals on the team see how their systems and related decisions connect to the bigger picture and affect mission success. The Chandra X-ray Observatory offers a practical example of these connections. The star tracker's designer must understand that the star tracker is part of an attitude control system—specifically, of an attitude estimator used to take precisely pointed observations—and that the star tracker's output determines whether or not the proper images are obtained. If the designer does not understand this, the project is in trouble. Good systems engineers can anticipate the impact of any change injected into the system or project, and describe the nature and magnitude of the impact throughout their system.

Exceptional two-way communicator. *Communications skills* are the great enabler. Systems engineers need to be able to get out of their offices and communicate well—listen, talk, and write. George Bernard Shaw once stated that England and America are "two countries separated by a common language," but engineers are separated by their **separate** languages—even more so since the advent of electronic communications. Systems engineering helps bridge the communication gaps among engineers and managers with consistent terms, processes, and procedures. A key to success is the ability to see, understand, and communicate the big picture, and be effective in helping others develop a big-picture view.

Strong team member and leader. Here we distinguish between management and leadership, realizing that a systems engineer must be skilled in both.

So far, we have described the characteristics that good systems engineers share. Ideally, as they gain experience, they are able to deal with more complex systems through

- Breadth of technical knowledge and expertise, combined with execution excellence
- Passion for the mission and challenges, combined with force of personality and leadership ability
- Creativity and engineering instinct —ability to sense the right way to attack a problem while appreciating inherent risks and implications
- Ability to teach and influence others

> While management and leadership are related and often treated as the same, their central functions are different. Managers clearly provide some leadership, and leaders obviously perform some management. However, there are unique functions performed by leaders that are not performed by managers. My observation over the past forty years...is that we develop a lot of good managers, but very few leaders. Let me explain the difference in functions they perform.
>
> - A manager takes care of where you are; a leader takes you to a new place
> - A manager is concerned with doing things right; a leader is concerned with doing the right things
> - A manager deals with complexity; a leader deals with uncertainty
> - A manager creates policies; a leader establishes principles
> - A manager sees and hears what is going on; a leader hears when there is no sound and sees when there is no light
> - A manager finds answers and solutions; a leader formulates the questions and identifies the problems
>
> *James E. Colvard*

Comfortable with change. Systems engineers should be *comfortable with change*. They understand that change is inevitable. They anticipate change, are able to understand how it affects their systems, and deal with those effects properly, usually without losing sleep at night.

> The number of changes must decrease with time. If projects continue to change, they will never get to the launch pad. This is particularly true with requirements. While it is undesirable to freeze them too early, it is much more likely that requirements will continue to change way too long. ...At some point, the design must be implemented, at which time "change" is the enemy.
>
> *Ken Ledbetter, NASA Headquarters*

Comfortable with uncertainty. A companion characteristic is being *comfortable with uncertainty*—indeed, embracing uncertainty. We usually do not know when we will finish a task, or even a mission. We know requirements are not complete, so we have to interpret them. This is the simple side of uncertainty. But uncertainty has a more complex side, so a strong background in probability and statistics is important. A good systems engineer understands and encourages quantification of uncertainty. For example, if the mission objective is to land a probe on a comet, the location and severity of jets or debris may be unknown or the comet's albedo may be uncertain. The systems engineer must be able to work with a team to design a system that accommodates the uncertainties.

Proper paranoia. Another important characteristic is *proper paranoia*: expecting the best, but thinking about and planning for the worst. This suggests that the systems engineer is constantly checking and crosschecking selected details across the system to be sure that technical integrity is intact.

Diverse technical skills. A systems engineer must be able to apply sound technical principles across *diverse technical disciplines*. Good systems engineers know the theory and practice of many technical disciplines, respect expert input, and can credibly interact with most discipline experts. They also have enough demonstrated engineering maturity to delve into and learn new technical areas that should be integrated into the system. They must be strong *technical leaders*, in addition to having broad technical competence. Systems engineers must meet the special challenge of commanding diverse technical knowledge, plus managing, **and** leading effectively!

Self confidence and decisiveness. Systems engineers must have well-earned *self-confidence*. They know what they know and are aware of what they do not know, and are not afraid to own both. It does not mean systems engineers never make mistakes. We have all made mistakes...at least occasionally.

> Commission, not omission. This should be written on the door of every systems engineer. There is no excuse for omission. A systems engineer does not need authority from anyone to investigate anything. The systems engineer's job is the whole space. You go out, you make decisions. If someone tells you to stop, you use your communication skills and listen.
>
> *Gentry Lee, Jet Propulsion Laboratory*

Appreciate the value of process. Good systems engineers *appreciate process*. That does not mean systems engineering is just one process, plus another, plus another—like recipes in a cookbook. Let us look back at our metaphor. To create the music of a symphony, musicians use their instruments, musical scores, and notes. These tools provide them with a common frame of reference, help them keep proper time, and allow the orchestra to work together to create beautiful music. Processes serve the same purpose for the systems engineer. But just providing sheets of music to a group of musicians does not guarantee a great orchestra. While each orchestra uses the same tools and many have very skilled musicians, they do not all sound like the New York Philharmonic.

Herein lies the art—how well does the maestro lead the people and use the tools provided? Maestros know how to bring out the best in their musicians; they know how to vary the tempo and the right moment to cue the horn section to draw in the listeners. The same is true for systems engineers. We must all use processes to get the job done, but it is what we DO with the processes and talents of the team that matters.

A successful systems engineer knows how to balance the art of technical leadership with the science of systems management. Both are required for success! The behavioral characteristics described above are necessary to meet the many challenges facing NASA's systems engineers today and in the future.

Realities of Complex System Design

To this point, we have defined systems engineering as a combination of technical leadership and systems management. We have established that highly effective systems engineers share certain behavioral characteristics. These elements feed into successful mission and system design: the ability to get a system's design right initially and to maintain its technical integrity throughout its lifecycle. There are numerous definitions of architecture and design. We use the following:

- Architecture encompasses the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution
- Design is creating a product or system, as well as a plan to develop and use it. For our purpose, architects provide the rules; designers create implementations using those rules.
- **Systems engineers do both**—help create the design and maintain its integrity throughout its lifecycle

Designing new aerospace missions and systems is a very creative, technical activity. Most engineers use a variation of a fundamental thought process—**D**efine the problem, **E**stablish selection criteria, **S**ynthesize alternatives, **A**nalyze alternatives, **C**ompare alternatives, **M**ake a decision, and **I**mplement (and Iterate, for that matter). Though not usually mandated, this process, or one very much like it, is applied because it produces good, useful results—it works! For shorthand, we will refer to this as DESACMI.

The first credible design for a space mission and its associated systems is usually the product of a few individuals or a small design team. They

- Capture and validate stakeholders' needs and success criteria
- Identify critical top-level requirements (normally 3 to 7) and understand the acceptance criteria
- Create a mission concept as well as physical and functional architectures
- Develop a concept of operations and integrate it with the mission concept, architecture, and top-level requirements
- Design critical interfaces among the architecture's elements
- Develop clear and unambiguous requirements that derive from the mission concept, architecture, concept of operations, and defined interfaces

The result of this intense, highly iterative, and creative activity is a first credible design that is consistent with basic physics or engineering principles and meets top-level requirements. It is a baseline from which we apply systems management processes to do tradeoffs and more detailed quantitative analyses that focus on enhancing the design detail. We also continue to identify and mitigate technical, cost, and schedule risks.

Tom Logsdon, a highly respected author of several books and thought-provoking papers in space systems, describes this activity in his book, *Six Simple, Creative Solutions That Shook the World*. He eloquently explains six steps that capture the creative approaches of highly creative people:

- Break the problem apart and put it back together again
- Take a fresh look at the interfaces
- Reformulate the problem
- Visualize a fruitful analogy
- Search for useful order-of-magnitude changes
- Be alert to happy serendipity

This book is worth its weight in gold—one reason it was renamed *The Midas Touch*!

Defining the interfaces is key. We have to keep the number of interfaces to an acceptable minimum; less is usually more provided the appropriate level of isolation of interaction is maintained. We should also keep them as simple as possible and, when confronted with a particularly difficult interface, try changing its characteristics. And of course, we have to watch out for Murphy's Law!

Designers and systems engineers engaged in this early activity, and indeed, throughout the lifecycle, follow several hard-learned principles: apply equal sweat, maintain healthy tension, manage margin, look for gaps and overlaps, produce a robust design, and study unintended consequences.

Eberhard Rechtin partly captures the essence of a first credible design of a space mission and its systems, as well as more refined or evolved designs, in System Architecting (which some would call system design):

- Relationships among the elements are what give systems their added value.
- Choosing the appropriate aggregation of functions is critical in the design of systems...In partitioning, choose the elements so that they are as independent as possible, that is, elements with low external complexity and high internal complexity...choose a configuration in which local activity is high speed and global activity is slow change...minimal communications between subsystems.
- The greatest leverage in system architecting and design is at the interfaces.

Apply equal sweat. The concept of *equal sweat* is to apportion the required performance or functional requirements, as much as possible, so that no single subsystem has an insurmountable problem. Figure 3 provides an example of the allocation and flow down of the top-level requirement for mapping error. If the mapping error is misallocated, it can easily drive the cost and complexity of one element up significantly, while allowing another element to launch with excess margin. Good engineering judgment and communication are required to allocate a requirement across subsystem boundaries in such a way that each element expends "equal sweat" in meeting the requirement. We must be prepared to reallocate when a problem becomes unexpectedly difficult in one area. To achieve this, team leaders must have established open communications and the expectation that the members can and should raise issues.

The concept of equal sweat applies to many aspects of space systems: spacecraft—pointing stability and knowledge; payload—line-of-sight, optical, thermal, and structural stability; operations—command complexity and recorder management; communications—total data volume and latency; data processing—artifact removal, data integrity verification, throughput, and reprocessing; and dissemination—metadata and archive management, to name a few.

Maintain healthy tension. A project must simultaneously meet its cost, schedule, and technical objectives. This often creates conflict. How much should we spend making the system better and how good is good enough? How much time and money must we spend in chasing down a problem? What risk will we take if we eliminate a test and how well do we understand that risk? Like the United States constitutional system, NASA's system of checks and balances is designed to ensure balancing of these objectives. If engineering becomes too focused on creating the perfect system, project management must push on cost and schedule. If project management becomes too focused on minimizing testing to reduce schedule, engineering or safety and mission assurance must push on the technical integrity. Discussions may become extremely complex and passionate but we need to keep the common goal of mission success at the forefront.

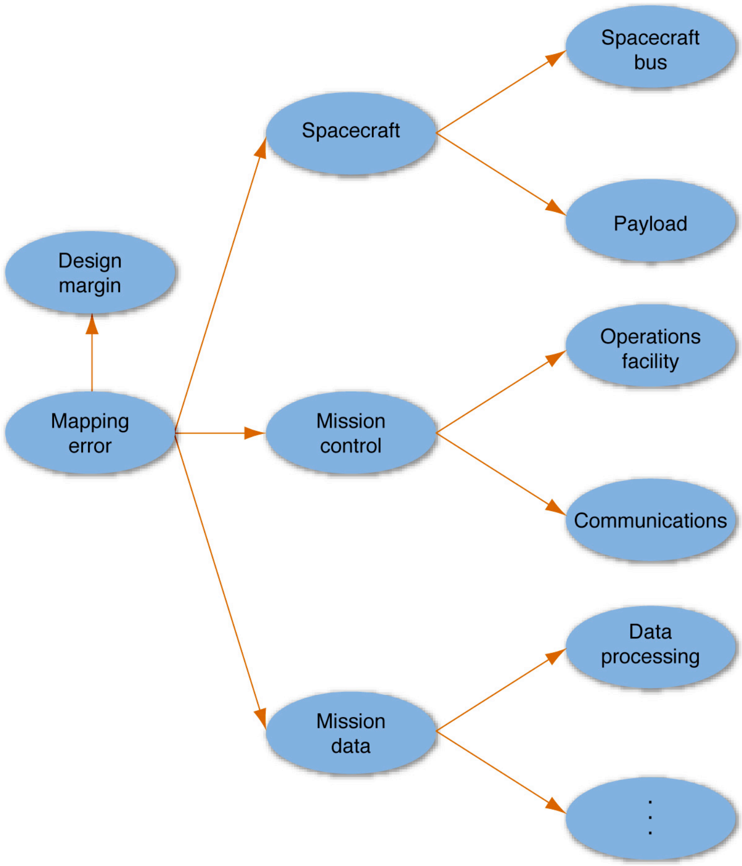


Figure 3. . **An Example of Equal Sweat.** Here we see a potential mapping error allocation for a space system. Mapping error represents how well the system is expected to pinpoint the location of an image created by the system. Zero mapping error is perfection. The goal, after setting sufficient design margin aside, is to allocate the mapping error to elements of the system in such a way that no element has an insurmountable challenge and each element expends roughly equal effort (sweat) in meeting the mapping error requirement.

Constructive dialogue among respectful peers along with the timely elevation of impasses is critical. It is vital to allow sufficient time for productive discussion while making timely decisions to move forward. The interactions may be individually stressful and appear to be wasteful, but NASA has a long history of mission successes when we maintained healthy tensions among all of the parties and conversely, a number of major failures when we did not.

Similar healthy tension occurs in many areas—across organizations, across subsystems or elements, and between mission phase requirements. This tension plays out during the design phase, when the operators try to be sure that the system will be operable and maintainable while the designers work to balance significant nearer term constraints such as cost, schedule, or mass. It also plays out during development and operations, when teams balance design changes and workarounds with ensuring safe, successful systems. Throughout the lifecycle this continual tension helps maintain the proper requirements, constraints, and testing. For example, we must strike a balance between too little and too much testing. Not enough testing adds risk to a program, whereas testing too much can be very costly and may add unnecessary run-time to the equipment. These healthy tensions are a key to creating and maintaining the environment that will produce the best-balanced system, and the systems engineer must embrace and foster them.

Manage margin. Good systems engineers maintain a running score of the product's resources: power, mass, delta-V, and many others. But more importantly, they **know the margins**. What exactly does margin mean? Margin is the difference between requirements and capability. If a spacecraft must do something, we allocate requirements. One way to add margin is to make the requirements a little tougher than absolutely necessary to meet the mission's level-one requirements, which some people call contingency. If we meet requirements, test effectively, and do the job correctly, we create a capability.

In Figure 4, the outer shape defines the capability, the inner shape represents the requirement, and the space between the two represents margin. The requirement comes very close to the capability (right side of the diagram), so we have a minimum margin.

It is not sufficient, systems engineers, to simply know the requirements and say, "Look we met our requirements." We must go beyond and be able to understand and articulate how much margin we have available in any situation. This gets us back to knowing the partial derivative of everything with respect to everything!

Gentry Lee, Jet Propulsion Laboratory

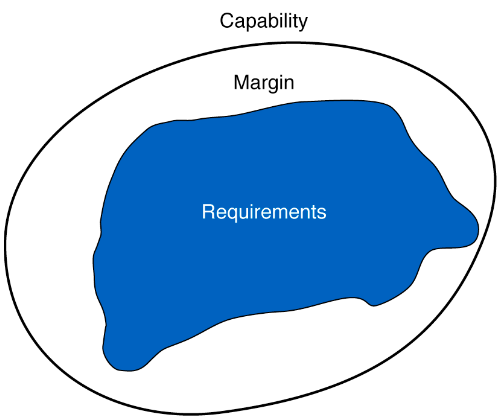


Figure 4. . **Requirements, Capability, and Margin.** Where the requirements come close to the capability (as on the right side of the figure), we have little margin.

Look for gaps and overlaps. Once we begin feeling comfortable and confident about our design, looking for gaps and overlaps will help us recover from our comfort and confidence. What have we forgotten? Which requirements are incomplete? Where are the disconnects among our project's top-level requirements, architecture, design, and concept of operations? We also must carefully consider all system interfaces and look on the other side of these interfaces to identify what could interfere with our system. When we do this we often find that our system of interest or the design's scope is not sufficiently defined.

Create a robust design. Robust design is a proven development philosophy focused on improving reliability of systems, products, and services. Other terms used to describe robust design include resilient, stable, flexible, and fault tolerant. Robust design is a key to successful missions and systems. To be useful, however, it must be an early and integral part of development. Our objective is to make our systems immune to factors that could harm performance and mission success. A robust design performs consistently as intended throughout its lifecycle, under a wide range of conditions and outside influences, and it resists unimaginable events. In other words, a robust design provides stability in the presence of ignorance!

Study unintended consequences. A key to our success in spaceflight is that we rigorously analyze failure modes and effects to determine how the system will perform when individual elements, subsystems, and, components fail. Good systems engineers study failures of complex systems, to gain insights into their root causes, ripple effects, and contributing factors. Hardware, software, interfaces, organizations, and people introduce complexity, so we study failures to avoid them. Henry Petroski, a professor at Duke University and author of *Success Through Failure*, points out that studying failures helps us better assess our design's unintended consequences. So the systems engineer should study as many failures as possible to develop good engineering judgment.

In *Apollo: The Race to the Moon*, Murray and Cox offer a stirring account of the Apollo 13 oxygen tank's explosion—a significant anomaly that resulted in mission failure. It shows how flight and ground crews creatively worked together to save the lives of the astronauts.

> Two examples of robust design.
>
> On Apollo 13, diverse systems in the lunar module (LM) allowed the crew to survive the transit to the Moon and back after the explosion. Then the manual attitude control capability, guided by the crew looking out the window and firing the command module reentry control system, allowed steering of the burns necessary to return to Earth. Using the LM as a lifeboat was considered during design, and contingency procedures were written before flight.
>
> In contrast is the near loss of the space station when all of the triplex redundant computer systems necessary for attitude control failed. There was no simple backup mode on the ISS. Luckily, the Shuttle was docked at the time, providing a diverse attitude control capability that allowed time and opportunity for the crew to find the problem, bypass it with jumper cables, and restore nominal attitude control. Had the Shuttle not been there, it might have been necessary to abandon the station to allow the crew to escape via the Soyuz before the station tumbled out of control.
>
> *Mike Bay, Goddard Space Flight Center*

By this point we have discussed the philosophy of mission and system design, reviewed hard-earned wisdom about design, and even applied what we have learned from previous failures to create our "first credible" design. We may hesitate to show the design to others until we have enhanced it a little more, a little more, and even a little more. In other words, it is hard to stop tweaking our design to make it better. Eventually, because of such realities as lack of money or time, we have to say: "Better is the enemy of good enough."

In universities, engineers learn to optimize designs, especially in the traditional electrical and mechanical disciplines. Typically, in a large, complex system design, competing requirements and constraints make optimized subsystems inappropriate. We need a balanced design that meets stakeholder

In this excerpt from *Apollo: The Race to the Moon*, Murray and Cox offer a stirring account of the Apollo 13 oxygen tank's explosion.

> ...In the end, NASA would find, this is what happened...In October 1968, when O_2 Tank 2 used in Apollo 13 was at North American, it was dropped. It was only a two-inch drop, and no one could detect any damage, but it seems likely that the jolt loosened the "fill tube" which put liquid oxygen into the tank.
>
> In March 1970, three weeks before the flight, Apollo 13 underwent its Countdown Demonstration Test...which involved loading all the cryos. When the test was over, O_2Tank 2 was still 92 percent full, and it wouldn't de-tank normally—probably because of the loose fill tube. Because a problem in the fill tube would have no effect on the tank's operation during flight, the malfunction was not thought to be relevant to flight safety.
>
> After three unsuccessful attempts to empty the tank, it was decided to boil off the oxygen by using the internal heater and fan. This was considered to be the best procedure because it reproduced the way the system would work during flight: heating the liquid oxygen, raising its pressure, converting it to a gas, and expelling it through the valves and pipes into the fuel cells where, in flight, it would react with the hydrogen. So they turned on the tank's heater.
>
> A technician working the night shift on Pad 39A was assigned to keep an eye on the tank temperature gauge and make sure that it did not go over 85 degrees Fahrenheit. It was not really necessary that a human serve this function, because a safety switch inside the tank would cut off the heaters if the temperature went beyond the safety limit. And, in reality, the safety margin built into the system meant that the temperatures could go considerably higher than 85 degrees without doing any damage. But the precautions were part of NASA's way of ensuring that nothing would go wrong.
>
> After some time, the technician noticed that the temperature had risen to 85 degrees, but all he had been told was that anything in excess of 85 degrees was a problem, so he let the heater run—about eight hours, in all. No one had told him that the gauge's limit was 85 degrees. That's as high as it could measure. Thus the technician could not tell that the temperatures inside the tank were actually rising toward a peak of approximately 1,000 degrees Fahrenheit, because the safety switch had failed.
>
> It had failed because of one small but crucial lapse in communication. Eight years earlier, in 1962, North American had awarded Beech Aircraft a subcontract to build the cryo tanks for the service module. The subcontract specified that the assembly was to use 28-volt D.C. power. Beech Aircraft in turn gave a small switch manufacturer a subcontract to supply the thermostatic safety switches, similarly specifying 28 volts. In 1965, North American instructed Beech to change the tank so that it could use a 65-volt D.C. power supply, the type that would be used at KSC during checkout. Beech did so, neglecting, however, to inform its subcontractor to change the power specification for their thermostatic safety switches. No one from Beech, North American, or NASA ever noticed this omission.
>
> On all the Apollo flights up through 12, the switches had not had to open. When the tanks were pressurized with cryogens hundreds of degrees below zero, the switches remained cool and closed. When, for the first time in the history of the cryo tanks, the temperature in the tanks rose high enough to trigger the switch—as O_2 Tank 2 emptied—the switch was instantaneously fused shut by the 65-volt surge of power that it had not been designed to handle. For the eight hours that the heaters remained on, the Teflon insulation on the wires inside the cryo tank baked and cracked open, exposing bare wires.
>
> On the evening of April 13...[when the cryo tank was stirred], some minute shift in the position of two of those bare wires resulted in an electrical short circuit, which in turn ignited the Teflon, heating the liquid oxygen. About sixteen seconds later, the pressure in the O_2 Tank 2 began to rise. The Teflon materials burned up toward the dome of the tank, where a larger amount of Teflon was concentrated, and the fire within the tank, fed by the liquid oxygen it was heating, grew fierce. In the final four seconds of this sequence, the pressure exceeded the limits of the tank in about eleven microseconds, slamming shut the reactant valves on Fuel Cell 1 and Fuel Cell 3. Then the Teflon insulation between the inner and outer shells of the tank caught fire, as did the Mylar lining in the interior of the service module. The resulting gases blew out one of the panels in the service module. That explosion also probably broke a small line that fed a pressure sensor on the outside of the O_2 Tank 1, opening a small leak.
>
> Once the service module panel blew out...

This true story is rich in content relevant to systems engineering. It includes examples of design, changes in requirements and their impact, technical data management, overall technical integrity, communications and decisions, transitions (from one contract to another, for example), interfaces, anomaly response, and processes, to name a few. It is worth taking a moment to think about the complexities of technical design, organization, and process that this single example demonstrates. Our job as systems engineers is to manage this complexity!

needs as well as top-level critical requirements and constraints. However, system constraints such as mass often require the overall system to be optimized.

Design is the creative act of managing constraints, organizing system complexity, developing effective interfaces, managing resources and margin, and injecting leading-edge technology when and where appropriate. Creating an architecture and design for a complex system often requires the use of proven processes to manage complexity.

Processes for Systems Engineers

Getting the design right is a key first step in creating, developing, and operating aerospace systems. This activity represents the 10-percent inspiration associated with an acceptable solution. Maintaining technical integrity and managing complexity using good solid processes represents the 90-percent perspiration necessary to deliver the needed products and services. No matter how brilliant the design, we must still understand and properly apply rigorous processes and procedures throughout the project's lifecycle. Otherwise, what seemed like the right design will have a high probability of failing to meet its intended mission, within cost and schedule. Systems engineers must be able to deal with broad technical issues and apply rigorous processes and procedures especially as projects get larger and more complex.

> Clarence "Kelly" Johnson, the legendary aerospace engineer from Lockheed, recognized this fact regarding the second generation of the U-2. The celebrated SR-71 reconnaissance aircraft had replaced the U-2 in the late 1960's. Johnson understood that many hard lessons learned while developing the U-2 might be needed in the future. When the U-2 was initially taken out of service, Johnson persuaded his management to preserve and archive, at great expense, the extensive database of processes, procedures, and tooling used to build the original U-2.
>
> That decision became prophetic. In 1979, many years after ending production of this outstanding aircraft, the mission was renewed and enhanced. First flown in 1955, the U-2 has had many variants performing a range of missions.

NASA has documented its systems-engineering policy in NPR-7123.1a, *NASA Systems Engineering*. This document was developed by researching the defense and commercial aerospace industry and building the best approach to bridging the communication gaps identified from many project reviews, anomaly reports, failure reports, and studies.

From experience we know that technical teams tend to ignore policy documents ("cookbooks") that dictate what they must do if the documents are not tailored to project circumstances and supported by complementary elements. Examples of these elements are "how-to" resources (such as SP-6105 (2007) and *Applied Space Systems Engineering*) education and training materials, on-the-job learning activities, and appropriate tools.

In summary, we need to preserve lessons learned and tried-and-true processes, as well as enhance communication and consistently apply processes and procedures throughout NASA. Solid processes enable good systems engineering of complex systems. The advice we offer systems engineers is to own the processes and tools, and know when and how to use them, but not to be owned by them. A lack of process rigor can easily lead to disaster, but too much process rigor can lead to rigor mortis. So our challenge is to develop systems engineers with good engineering judgment who know how to take a balanced approach. The goal of a process is to provide the needed product or service!

Because systems engineering is both an art and a science, many of the skills and abilities needed to be highly effective in complex systems are not learned in school; they are gained through experience. Processes and tools are very important, but they can not substitute for capable people. Following processes and using tool sets will not result automatically in a good systems engineer or system design. Entering requirements into a database does not make them the right requirements. Having the spacecraft design in a computer-aided design (CAD) system does not make it the right design. Capable and well-prepared people make the difference between success and failure.

The Best Preparation

So how do aspiring systems engineers prepare themselves for such a challenge? Abraham Lincoln had it right when he said, "If I had eight hours to chop down a tree, I'd spend six hours sharpening my ax." But what is the best way to sharpen our axes?

We recommend that if you are an aspiring systems engineer, you embrace the personal behavioral characteristics described above and become proficient in APPEL's systems engineering competencies.* Then, decide what capabilities and experiences you have and what you still need to develop. Once you have assessed your capabilities, the best (some would say the ONLY) way to learn systems engineering is by doing it! It is a good idea to strive for assignments that allow one to develop, deliver, or operate hardware and software systems. Mike Griffin recommends participating in as many "hanger-flying" sessions as possible, spending time with experienced systems engineers and learning from their stories. Everyone is different, and there are many ways to proceed, but a career in systems engineering may unfold as shown in Figure 5.

Figure 6 demonstrates that, as systems engineers develop, they are better able to affect a project's success, even while dealing with increasing complexity. It also points out that the tried-and-true approach to cultivating systems engineering talent is through apprenticeship, mentoring, and on-the-job training—augmented by formal training and education. The best way to become a good systems engineer is to "get your hands dirty" with hands-on experience in multiple disciplines.

NASA has very robust education and training for program or project managers and systems engineers. With many courses and development opportunities, NASA employees have an excellent foundation from which to acquire the knowledge and information they need to improve these capabilities.

* URL's containing additional information for this section can be found in the bibliography under Links.

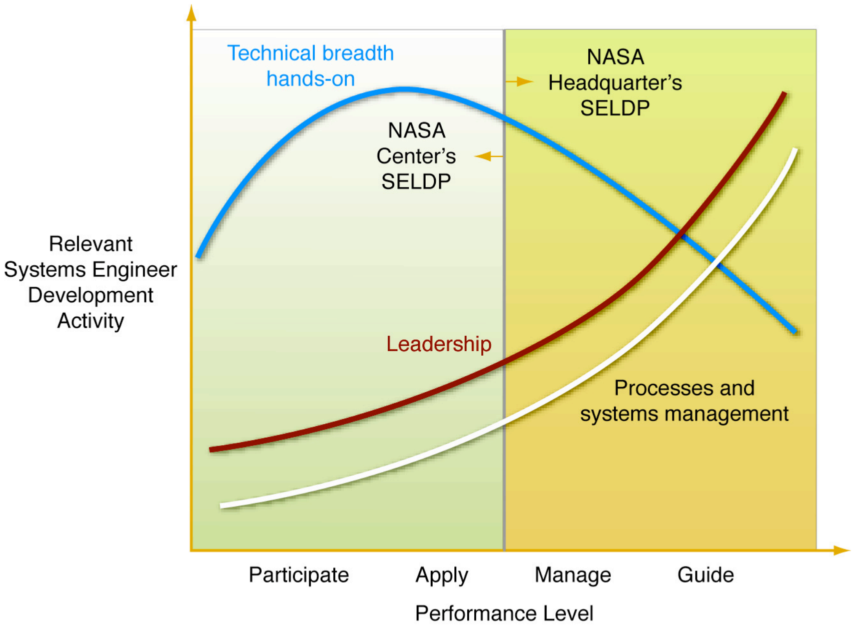


Figure 5. . **Development Activities for Systems Engineers by Performance Level.** Systems engineers develop in three ways: technical breadth, systems management, and leadership. Early in a systems engineer's career—at the first two performance levels (participate and apply), the focus is mainly on developing technical breadth. That breadth develops through hands-on hardware and software experience, as well as growing abilities in systems management and leadership. Systems engineers usually need much greater leadership and systems-management skills later in their careers in the next two performance levels (manage and guide). SELDP is the Systems Engineering Leadership Development Program.

Who in NASA is responsible for a system engineer's development? The supervisor? The NASA Administrator? The Academy of Program, Project and Engineering Leadership? No. Each person is responsible for his or her own development. Figure 7 provides options and guidance. Many people are willing to be coaches and mentors, and to offer opportunities, but it is up to individuals to plan their own professional development.

The Systems Engineering Leadership Development Program (SELDP) provides development activities, training, and education through APPEL. The rationale for the "participate" and "apply" performance levels is provided in NASA's *Integrated Technical Workforce Career Development Model*—created by the Office of the Chief Engineer (OCE) under the leadership of Bob Menrad from Goddard Space Flight Center. The development activities, education, and training for the "manage" and "guide" performance levels derive from two sources: *Coaching Valuable Systems Engineering Behaviors* by M. E. Derro and P. A. Jansma from the Jet Propulsion Laboratory and *NASA's Systems Engineering Behavior*

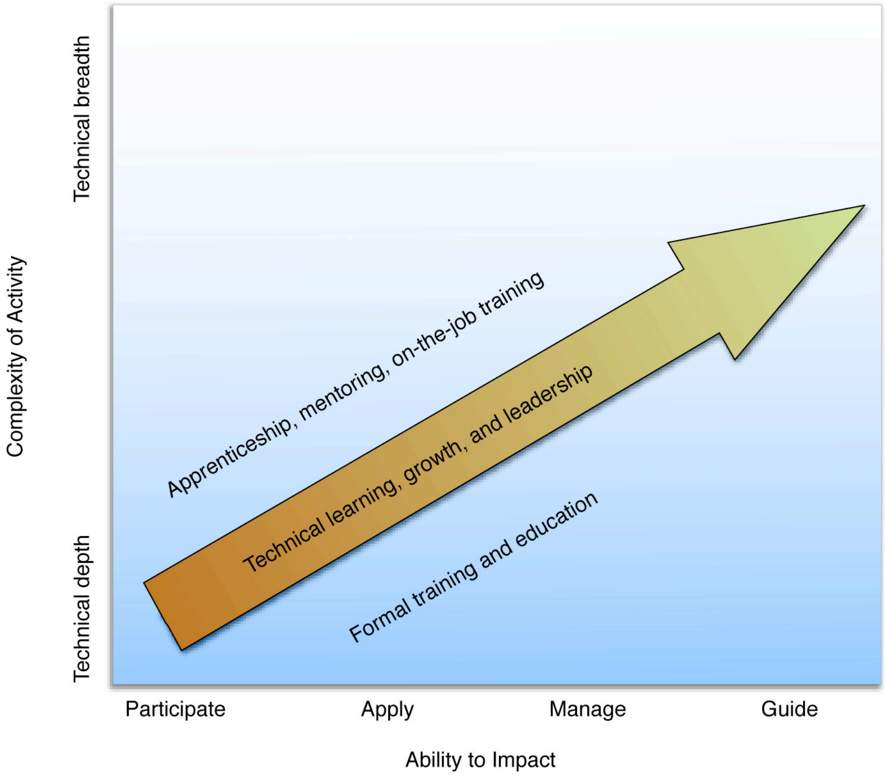


Figure 6. . Another Perspective on Development Activities for Systems Engineers. As systems engineers progress from one performance level to the next, they undertake increasingly complex activities and learn that they can more strongly affect how these activities play out. The tried-and-true method of developing systems engineers is through apprenticeship, mentoring, and on-the-job training—augmented as necessary by formal training and education.

Study, by Christine Williams and Mary-Ellen Derro. NASA has identified five main behaviors for success that are assessed and coached as part of the Systems Engineering Leadership Development Program:

- Leadership skills—Demonstrates ability to influence others, work with a team, develop trusting relationships, communicate vision and technical approach, and mentor and coach less-experienced systems engineers
- Attitudes and attributes—Exhibits intellectual self-confidence, intellectual curiosity, and ability to manage change, remain objective, and maintain healthy skepticism

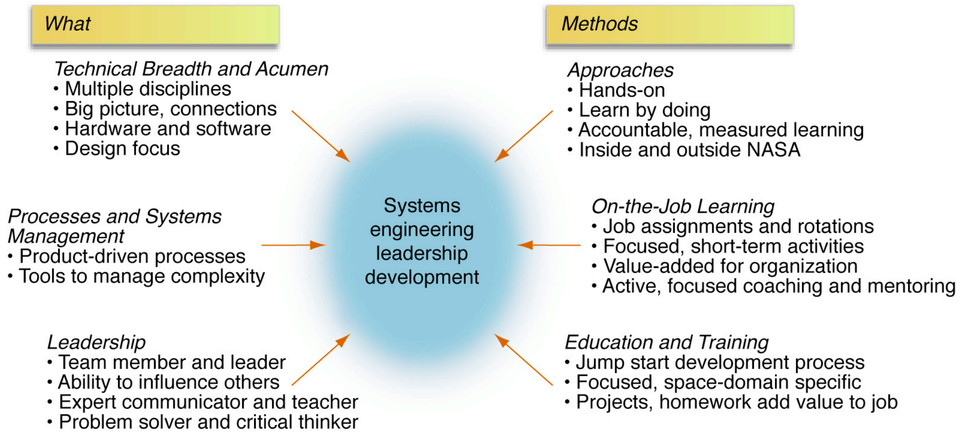


Figure 7. . Options for Developing Leadership in Systems Engineering. This figure helps focus system-engineering development activities and identifies the most beneficial approaches.

- Communication—Successfully advances ideas and fosters two-way discussions, communicates through storytelling and analogies, listens and translates information
- Problem solving and critical thinking—Manages risk, thinks critically, and penetrates issues in a logical manner
- Technical acumen—Demonstrates technical breadth and competency, ability to learn new technology, applies experience and lessons learned from successes and failures

Summary

Systems engineering at NASA, and throughout the aerospace industry, is an art and a science, so anyone with the title "systems engineer" must be able to handle both technical leadership and systems management. In fact, both are critical to maintaining technical integrity throughout the development and operation of space systems. We place high value on technically competent systems engineers with diverse technical skills who are highly effective in leading teams and managing systems.

We discussed the personal characteristics of many of NASA's best systems engineers to help aspiring systems engineers better understand the nature of the profession and what is expected of them. We also described selected aspects of designing aerospace systems to demonstrate the importance of the architecture, design, and concept of operations to project success. We believe good systems engineers must understand and embrace the tenets of robust design and be able to participate in designing aerospace missions and systems.

We have documented the capabilities that a systems engineer at NASA must have at each performance level. NPR 7123.1a also includes fundamental processes that characterize systems engineering activities across NASA.

Systems engineering is a critical skill within NASA and the entire aerospace community. The Chief Engineer of NASA, working with counterparts at all Centers, has created a wealth of information and opportunities to help develop systems engineers at NASA. The Academy of Program, Project and Engineering Leadership has created a Systems Engineering Leadership Development Program to identify strong candidates for further development and provide opportunities for growth. Many NASA Centers have also created programs to develop their systems engineers. Anyone who is interested in honing his or her systems engineering skills is encouraged to approach the organization's leaders and persist in the quest to grow and develop as a systems engineer.

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The Art and Science of Systems Engineering*

The Scope of Systems Engineering

The Personal Characteristics of Good Systems Engineer

Summary

This work culminates years of experience in systems engineering and focused discussions among NASA leadership, systems engineers, and systems engineering trainers across the Agency. One consistent theme in these experiences and discussions is that NASA uses many definitions and descriptions of systems engineering. We use the terms and job titles of chief engineer, mission systems engineer, systems engineering and integration manager, system architect, vehicle integration, and so on for various pieces of the complete systems engineering function. We need to agree on a common understanding of systems engineering. In addition, no matter how we divide the roles and responsibilities among people, we must ensure that those roles and responsibilities are clear and executed as a functional whole. **Our objectives are to provide a clear definition of systems engineering, describe the highly-effective behavioral characteristics of our best systems engineers and make explicit the expectations of systems engineers at NASA.**

Systems engineering is both an art and a science. We can compare systems engineering to an orchestra and its ability to perform a symphony. Most people understand what music is, but not everyone can play an instrument. Each instrument requires a different level of expertise and skill. Some musicians spend their entire careers mastering a single instrument, which is good because each one needs to be played well. But sophisticated music involves many different instruments played in unison. Depending on how well they come together, they may produce beautiful music or a terrible cacophony.

We can think of a symphony as a system. The musicians apply the science of music: they follow the process of translating notes on a page to play their instruments. But an orchestra conductor, a maestro, must lead them to connect the process of playing to the art of creating great music. Maestros do a lot more than just keep time! They:

* Systems engineering is a critical core competency for successful NASA missions. This paper summarizes the collective wisdom of some of NASA's best technical minds on the subject. So here the word "we" represents all contributors to this effort: Michael Bay, Bill Gerstenmaier, Mike Griffin, Jack Knight, Wiley Larson, Ken Ledbetter, Gentry Lee, Michael Menzel, Brian Muirhead, John Muratore, Bob Ryan, Mike Ryschkewitsch, Dawn Schaible, Chris Scolese, and Chris Williams. Among them, they have more than 390 years—almost four centuries—of experience in aerospace and systems engineering.

- Know and understand music—such matters as pitch, rhythm, dynamics, and sonic qualities—as well as the capabilities of various instruments and musicians
- Are necessary once the orchestra reaches a certain size and complexity
- Have typically mastered one or more musical instruments
- May be composers
- Select and shape the music that an orchestra plays
- Interpret a composer’s music in light of the audience
- Strive to maintain the integrity of the composer's intentions
- Organize and lead the musicians
- Are responsible for the success of the performance

The systems engineer is like the maestro, who knows what the music should sound like (the look and function of a design) and has the skills to lead a team in achieving the desired sound (meeting the system requirements). Systems engineers:

- Understand the fundamentals of mathematics, physics, and other pertinent sciences, as well as the capabilities of various people and disciplines
- Have mastered a technical discipline and learned multiple disciplines
- Must understand the end game and overall objectives of the endeavor
- Create a vision and approach for attaining the objectives
- May be architects or designers
- Select and shape the technical issues to be addressed by multidisciplinary teams
- Must often interpret and communicate objectives, requirements, system architecture, and design
- Are responsible for the design’s technical integrity
- Organize and lead multidisciplinary teams
- Are responsible for the successful delivery of a complex product or service

> A great systems engineer completely understands and applies the art of **leadership** and has the experience and scar tissue from trying to **earn** the badge of **leader** from his or her team.
>
> *Harold Bell*
> *NASA Headquarters*

The similarities between maestros and systems engineers are useful in describing the latters’ desired behavioral characteristics and capabilities.

Systems engineering is the art and science of developing an operable system that meets requirements within imposed constraints. This definition is independent of scale, but our discussion here focuses on developing complex systems, such as aircraft, spacecraft, power plants, and computer networks.

Systems engineering is holistic and integrative. It incorporates and balances the contributions of structural, mechanical, electrical, software, systems safety, and power engineers, plus many other, to produce a coherent whole. Systems engineering is about tradeoffs and compromises, about generalists rather than specialists.

Systems engineering is not only about the details of requirements and interfaces among subsystems. Such details are important, of course, in the same way that accurate accounting is important to an organization's chief financial officer. But accurate accounting does not distinguish between a good financial plan and a bad one, nor help to make a bad one better. Similarly, accurate control of interfaces and requirements is necessary to good systems engineering, but no amount of care in such matters can make a poor design concept better. **Systems engineering is first and foremost about getting the right design**—and then about maintaining and enhancing its technical integrity, as well as managing complexity with good processes to get the design right. We define interfaces in a system design to minimize unintended interactions and simplify development and operations—and then we document and control the design. Neither the world's greatest design, poorly implemented—nor a poor design, brilliantly implemented—is worth having.

The principles of systems engineering apply at all levels. For example, engineers who are developing an avionics system must practice creative design and interface definition to achieve their goals. Similar activities are essential to the architecture, design, and development of elements and subsystems across the broad spectrum of NASA developments. But for the remainder of this discussion, we use the term "systems engineering" in the context of complex, multidisciplinary system definition, development, and operation.

In his 2007 presentation, "Systems Engineering and the 'Two Cultures' of Engineering," Mike Griffin describes how the complexities of today's aerospace systems and the ways they fail have led to branching within the industry. For our purpose, we divide systems engineering into technical leadership and its ally, systems management.

- Technical leadership focuses on a system's technical design and technical integrity throughout its lifecycle
- Systems management focuses on managing the complexity associated with having many technical disciplines, multiple organizations, and hundreds or thousands of people engaged in a highly technical activity

> Once a credible design and architecture are established, the systems engineer's job is to maintain technical integrity throughout the complex system's very rigorous and challenging lifecycle phases.
>
> *Robert Ryan, Marshall Space Flight Center*

Technical leadership, the *art* of systems engineering, balances broad technical domain knowledge, engineering instinct, problem solving, creativity, leadership, and communication to develop new missions and systems. It is the system's complexity, and severity of its constraints—not just its size—that drives the need for systems engineering.

NASA systems are often large and complex, so they require systems engineers to work in teams and with technical and other professional experts to maintain and enhance the system's technical integrity. The creativity and knowledge of all of the people involved must be brought to bear to achieve success. Thus leadership and communications skills are often as important as technical acumen and creativity. This part of systems engineering is about doing the job right.

For large complex systems, there are literally millions of ways to fail to meet objectives, even after we have defined the "right system." It is crucial to work all the details completely and consistently and ensure that the designs and technical activities of all the people and organizations remain coordinated—art is not enough.

Systems management is the *science* of systems engineering. Its focus is on rigorously and efficiently managing the development and operation of complex systems. Effective systems management requires applying a systematic, disciplined engineering approach that is quantifiable, recursive, repeatable, and demonstrable. Here the emphasis is on organizational skills, processes, and persistence. Process definition and control are essential to effective, efficient, and consistent implementation. They demand a clear understanding and communication of the objectives, and vigilance in making sure that all tasks directly support the objectives.

Systems management provides a framework for problem solving...creative problem solving for complex systems.

Dinesh Verma,
Stevens Institute of Technology

One of the biggest challenges for a systems engineer of a large complex project is to "bring order from chaos."

Chris Hardcastle,
Systems Engineering and Integration Manager, NASA's Constellation Program, Johnson Space Center

Systems management applies to developing, operating, and maintaining integrated systems throughout a project or program's lifecycle, which may extend for decades. Since the lifecycle may exceed the memory of the individuals involved in the development, it is critical to document the essential information.

To succeed, we must blend technical leadership and systems management into complete systems engineering. Anything less results in systems not worth having or that fail to function or perform.

The Scope of Systems Engineering

Since the late 1980's, many aerospace-related government and industry organizations have moved from a hard-core, technical leadership culture (the art) to one of systems management (the science). History has shown that many projects dominated by only one of these cultures suffer significant ill consequences. Organizations that focus mainly on systems management often create products that fail to meet stakeholder objectives or are not cost effective. The process often becomes an end unto itself, and we experience "process paralysis." Organizations that focus solely on technical issues often create products or services that are inoperable, or suffer from lack of coordination and become too expensive or belated to be useful.

To achieve mission success, we must identify and develop systems engineers that are highly competent in both technical leadership and systems management. That is why we focus on the complete systems engineer, who embodies the art **and** science of systems engineering across all phases of aerospace missions—a type reflected in Figure 1. In any project, it is critical that systems engineering be performed well during all lifecycle phases. The scope of systems engineering and the associated roles and responsibilities of a systems engineer on a project are often negotiated by the project manager and the systems engineer. The scope of systems engineering and the activities for which the systems engineer is both responsible and accountable should be understood and documented early in the project.

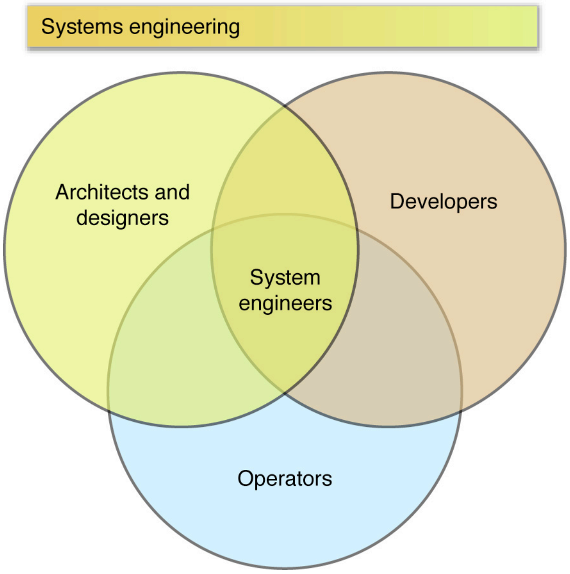

Figure 1. **The Scope of Systems Engineering.** Systems engineers often focus on one lifecycle phase like architecture and design versus development or operations, but good systems engineers have knowledge of and experience in all phases.

Here we describe the characteristics, some innate and others that we can develop, that enable select people to "systems engineer" complex aerospace missions and systems—to design, develop, and operate them. Then, we focus on how to further develop NASA's systems engineers to help them deal better with the complexities of sophisticated missions and systems.

The Personal Characteristics of Good Systems Engineers

Figure 2 depicts the personal behavioral characteristics of effective systems engineers.

Intellectual curiosity. Perhaps the most important personal characteristic of successful systems engineers is *intellectual curiosity*. People who prefer boundaries around their work to be comfortable, know what they know, and enjoy a focused domain may want to consider another occupation. Systems engineers continually try to understand the what, why, and how of their jobs, as well as other disciplines and situations that other people face. They are always encountering new technologies, ideas, and challenges, so they must feel comfortable with perpetual learning.

> People who have "systems engineer" in their title, regardless of the modifiers —project, program, flight system, and so on—are responsible for everything. "
>
> *Gentry Lee, Jet Propulsion Laboratory* '

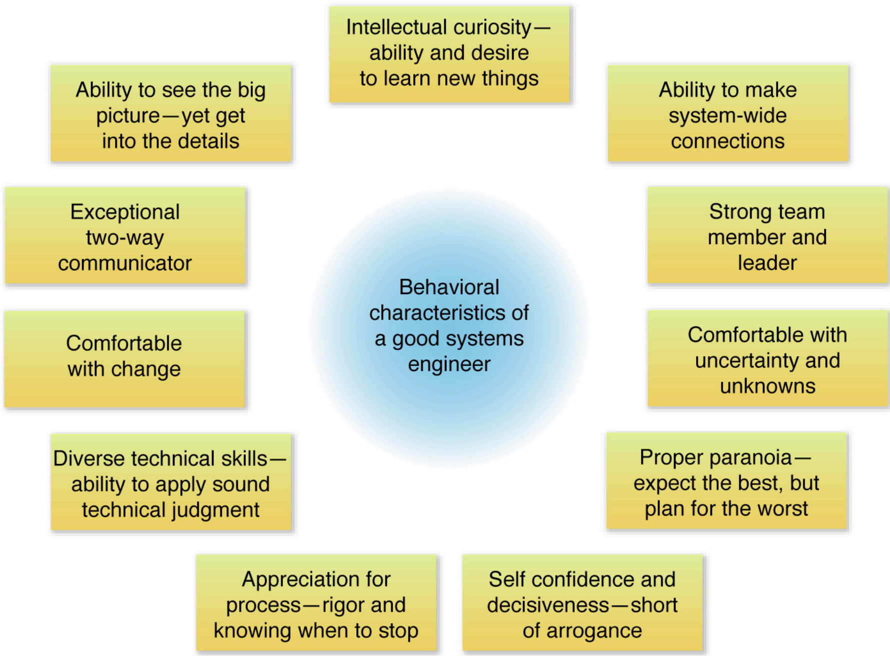

Figure 2. **Characteristics of a Good Systems Engineer.** The characteristics are shown in decreasing priority from top to bottom. Some of them are innate, whereas others can be learned and honed.

Ability to see the big picture. Good systems engineers maintain a *big-picture perspective*. They understand that their role, though always significant, changes throughout a project's lifecycle. At any point in the lifecycle the systems engineer must be fully cognizant of what has been done, what is necessary, and what remains to be done. Each phase has a different emphasis:

- Concept—mission and systems architecture, design, concept of operations, and trade studies
- Development—maintaining technical integrity throughout all lifecycle phases: preliminary design review, critical design review, verification, validation, and launch
- Operations—making sure that the project meets mission requirements and maintains technical integrity

Systems engineers pay particular attention to verification and validation. Verification answers the question: "Did we build our system right?" If we are successful, it proves our product meets the requirements. We emphasize the hard-earned lesson, "Test like you fly, fly like you test." Validation, on the other hand, answers the question: "Did we build the right system?" If we are successful, the system does what it is supposed to do, which often goes well beyond just meeting requirements!

Good systems engineers are able to "translate" for scientists, developers, operators, and other stakeholders. For example, "Discover and understand the relationship between newborn stars and cores of molecular clouds," is meaningful to a scientist. But developers and operators would better understand and use this version: "Observe 1,000 stars over two years, with a repeat cycle of once every five months, using each of the four payload instruments." The systems engineer that knows the project's objectives, helps determine how to meet them, and maintains the system's technical integrity throughout its lifecycle has a good chance of succeeding. A corollary is to check everyone's understanding of each other to make sure the team truly IS on the same page.

Ability to make system-wide connections. First-rate systems engineers understand the *connections* among all elements of a mission or system. They must often help individuals on the team see how their systems and related decisions connect to the bigger picture and affect mission success. The Chandra X-ray Observatory offers a practical example of these connections. The star tracker's designer must understand that the star tracker is part of an attitude control system—specifically, of an attitude estimator used to take precisely pointed observations—and that the star tracker's output determines whether or not the proper images are obtained. If the designer does not understand this, the project is in trouble. Good systems engineers can anticipate the impact of any change injected into the system or project, and describe the nature and magnitude of the impact throughout their system.

Exceptional two-way communicator. *Communications skills* are the great enabler. Systems engineers need to be able to get out of their offices and communicate well—listen, talk, and write. George Bernard Shaw once stated that England and America are "two countries separated by a common language," but engineers are separated by their **separate** languages—even more so since the advent of electronic communications. Systems engineering helps bridge the communication gaps among engineers and managers with consistent terms, processes, and procedures. A key to success is the ability to see, understand, and communicate the big picture, and be effective in helping others develop a big-picture view.

Strong team member and leader. Here we distinguish between management and leadership, realizing that a systems engineer must be skilled in both.

So far, we have described the characteristics that good systems engineers share. Ideally, as they gain experience, they are able to deal with more complex systems through

- Breadth of technical knowledge and expertise, combined with execution excellence
- Passion for the mission and challenges, combined with force of personality and leadership ability
- Creativity and engineering instinct —ability to sense the right way to attack a problem while appreciating inherent risks and implications
- Ability to teach and influence others

While management and leadership are related and often treated as the same, their central functions are different. Managers clearly provide some leadership, and leaders obviously perform some management. However, there are unique functions performed by leaders that are not performed by managers. My observation over the past forty years...is that we develop a lot of good managers, but very few leaders. Let me explain the difference in functions they perform.

- A manager takes care of where you are; a leader takes you to a new place
- A manager is concerned with doing things right; a leader is concerned with doing the right things
- A manager deals with complexity; a leader deals with uncertainty
- A manager creates policies; a leader establishes principles
- A manager sees and hears what is going on; a leader hears when there is no sound and sees when there is no light
- A manager finds answers and solutions; a leader formulates the questions and identifies the problems

James E. Colvard

The number of changes must decrease with time. If projects continue to change, they will never get to the launch pad. This is particularly true with requirements. While it is undesirable to freeze them too early, it is much more likely that requirements will continue to change way too long. ...At some point, the design must be implemented, at which time “change” is the enemy.

Ken Ledbetter, NASA Headquarters

Comfortable with change. Systems engineers should be *comfortable with change*. They understand that change is inevitable. They anticipate change, are able to understand how it affects their systems, and deal with those effects properly, usually without losing sleep at night.

Comfortable with uncertainty. A companion characteristic is being *comfortable with uncertainty*—indeed, embracing uncertainty. We usually do not know when we will finish a task, or even a mission. We know requirements are not complete, so we have to interpret them. This is the simple side of uncertainty. But uncertainty has a more complex side, so a strong background in probability and statistics is important. A good systems engineer understands and encourages quantification of uncertainty. For example, if the mission objective is to land a probe on a comet, the location and severity of jets or debris may be unknown or the comet’s albedo may be uncertain. The systems engineer must be able to work with a team to design a system that accommodates the uncertainties.

Proper paranoia. Another important characteristic is *proper paranoia*: expecting the best, but thinking about and planning for the worst. This suggests that the systems engineer is constantly checking and crosschecking selected details across the system to be sure that technical integrity is intact.

Diverse technical skills. A systems engineer must be able to apply sound technical principles across *diverse technical disciplines*. Good systems engineers know the theory and practice of many technical disciplines, respect expert input, and can credibly interact with most discipline experts. They also have enough demonstrated engineering maturity to delve into and learn new technical areas that should be integrated into the system. They must be strong *technical leaders*, in addition to having broad technical competence. Systems engineers must meet the special challenge of commanding diverse technical knowledge, plus managing, **and** leading effectively!

> Commission, not omission. This should be written on the door of every systems engineer. There is no excuse for omission. A systems engineer does not need authority from anyone to investigate anything. The systems engineer's job is the whole space. You go out, you make decisions. If someone tells you to stop, you use your communication skills and listen. "
>
> *Gentry Lee, Jet Propulsion Laboratory* '

Self confidence and decisiveness. Systems engineers must have well-earned *self-confidence*. They know what they know and are aware of what they do not know, and are not afraid to own both. It does not mean systems engineers never make mistakes. We have all made mistakes...at least occasionally.

Appreciate the value of process. Good systems engineers *appreciate process*. That does not mean systems engineering is just one process, plus another, plus another—like recipes in a cookbook. Let us look back at our metaphor. To create the music of a symphony, musicians use their instruments, musical scores, and notes. These tools provide them with a common frame of reference, help them keep proper time, and allow the orchestra to work together to create beautiful music. Processes serve the same purpose for the systems engineer. But just providing sheets of music to a group of musicians does not guarantee a great orchestra. While each orchestra uses the same tools and many have very skilled musicians, they do not all sound like the New York Philharmonic.

Herein lies the art—how well does the maestro lead the people and use the tools provided? Maestros know how to bring out the best in their musicians; they know how to vary the tempo and the right moment to cue the horn section to draw in the listeners. The same is true for systems engineers. We must all use processes to get the job done, but it is what we DO with the processes and talents of the team that matters.

Summary

Systems engineering is a crucial core competency within NASA. Systems engineering has two key components: technical leadership, the art, and systems management, the science, that are necessary for mission success. Technical leadership balances broad technical domain knowledge, engineering instinct, problem solving, creativity, leadership, and communication to develop and maintain new missions and systems at NASA.

Systems management's focus is on rigorously and efficiently managing the development and operation of complex systems. Effective systems management requires applying a systematic, disciplined engineering approach that is quantifiable, recursive, repeatable, and demonstrable. Here the emphasis is on organizational skills, processes, and persistence.

Systems engineering at NASA is most successful when there is a healthy balance of technical leadership and systems management engaged in a project.

Systems engineers are a critical resource for the Agency, and as such, we are dedicated to develop highly capable systems engineers that are able to lead and manage our missions and systems.

Executive Leadership at NASA: A Behavioral Framework

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March 2010

NASA Office of the Chief Engineer

Academy of Program/Project & Engineering Leadership

ATTACHMENT C

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Executive Leadership at NASA: A Behavioral Framework

1.0 Executive Summary

This is the second of two studies NASA's Office of the Chief Engineer conducted to identify characteristics or behaviors frequently observed in highly regarded systems engineers and technical executives. The purpose of these studies is to develop shared understanding and agreement across the agency regarding the practice of systems engineering, a core competency critical to NASA's success, and of the behaviors and attributes that enable highly regarded technical managers and executives to be successful.

The first study, the *NASA Systems Engineering Behavior Study,* conducted from March through October 2008, included 38 civil servants who were still actively engaged in systems engineering roles at NASA field centers. Study findings on behaviors and attributes of these highly regarded systems engineers are being used in the Systems Engineering Leadership Development Program (SELDP) and elsewhere to design and update systems engineering training, development, coaching, and mentoring programs. The goal of the study was to accelerate development of identified behaviors in systems engineers and to help NASA's engineering leadership more quickly identify and support the development of employees with high potential for future systems engineering leadership positions. (For a copy of the study and information on SELDP, please see: http://www.nasa.gov/offices/oce/appel/seldp/index.html.)

This current study, *Executive Leadership at NASA: A Behavioral Framework,* was conducted from June 2008 to March 2009. It investigated behaviors and attributes of 14 NASA executives at NASA Headquarters and field centers whom agency leadership identified as highly effective in their roles, and who possessed a technical background or systems orientation that contributed to their success. Study methodology and protocol mirrored that used in the *NASA Systems Engineering Behavior Study.* It included interviewing, observing and shadowing participants. Findings identified a shared set of effective executive behaviors evident across centers, reinforced and extended those of the previous study and resulted in a behavioral framework for technical managers seeking to transition into executive roles.

Data gathered to answer the question "What are the behaviors and attributes that enable individuals to become successful executives at NASA?" clustered into elements within six broad themes. Four of these—leadership, attitudes and attributes, communication, and problem solving and systems thinking—were among the five identified in the earlier study. In the current study, executive presence emerged as a sub-theme within attitudes and attributes, and two new themes, political savvy and strategic thinking, also surfaced.

This extended study has allowed us to identify behaviors and attributes that enable individuals to become successful NASA executives who achieve mission success. These findings, combined with those from the previous study, will contribute to agency efforts to create training and learning strategies that support career-long employee development and to ensure that NASA has executives ready and able to take on the complex work of leading NASA's future missions. This report presents the six broad themes identified from the interviews, observations, and shadowing activities, as well as the associated representative observable behaviors and attributes.

2.0 Introduction

2.1 Purpose

The purpose of this study, *Executive Leadership at NASA: A Behavioral Framework,* was to identify behaviors and attributes exhibited by the agency's most successful executives. Participants included NASA executives who served at some point in their NASA careers as technical managers of projects requiring systems development, possessed a systems engineering orientation, and successfully applied those talents and behaviors in their executive roles.

The information gained from this study will be used to accelerate the development of these critical behaviors in order to enhance the likelihood of mission success and to develop the next generation of highly regarded NASA executives.

Study findings will be used to design or update training, development, coaching, mentoring and knowledge sharing programs and materials to foster these behaviors in technical managers and others across the agency. Moreover, study data will allow NASA to introduce elements of executive development into training curricula used for multiple levels of the workforce. This will enable individuals to begin building knowledge, skills, behaviors and attributes central to executive leadership early in their careers.

Knowing specifically which characteristics or behaviors to target for development also provides the agency with a research-based framework from which to measure an individual's progress and the impact of training and development programs, and to assess individual influence on mission performance.

This study is also intended to provide NASA's leadership with a valid and reliable template from which to evaluate employees' capabilities as they relate to these behaviors and identify areas for development and improvement.

2.2 Background

In October 2008, NASA completed the *NASA Systems Engineering Behavior Study*, designed to identify the behaviors that separate high performing systems engineers at NASA from average performers. This study looked at 38 "highly regarded" practicing engineers to determine the behaviors that helped make them successful. The Office of the Chief Engineer immediately began to incorporate study findings into training programs and into the newly created Systems Engineering Leadership Development Program (SELDP).

Prior to the start of this first study, the Office of the Chief Engineer and former NASA Administrator determined that the differences in the roles and responsibilities of practicing systems engineers and NASA executives using systems engineering skills warranted separate studies.

3.0 Methodology

3.1 Behavior Study Approach

NASA leaders agreed that the study would focus on identifying behaviors that enabled executives to be successful at NASA, i.e., to achieve mission success, and they selected study participants whom they considered “highly successful” executives.

While the majority of those identified were from the systems engineering community, others had different backgrounds (e.g.. project management). All, however, had a systems orientation[1] and a technical background in one or more engineering sub-disciplines. One participant was retired. The remaining executives worked at NASA Headquarters or one of the NASA field centers. See Appendix 1 for a list of those interviewed.

The Office of the Chief Engineer (OCE) selected team members with prior experience working on the *NASA Systems Engineering Behavior Study* and with education and experience in organizational development and/or training and development.

The methodology of both the current study and the *NASA Systems Engineering Behavior Study* was based on the work previously done at the Jet Propulsion Laboratory (JPL) for the Systems Engineering Advancement Program. One or more of the study team members interviewed, shadowed and/or observed each of the executive participants. The interviews, conducted and recorded in conference rooms or private offices, were from 60 to 90 minutes long. The questions were vetted and approved by the NASA Chief Engineer prior to the start of the study. Participants were asked identical questions, with follow-up questions based on initial answers. Interview questions were divided into two categories: context and relation to self and personal awareness. See Figure 1 for a list of questions asked.

Context Questions

1. How would you describe the role of an SE executive

Relation to Self and Personal Awareness

2. Describe top performing executive SE’s in behavioral terms?
3. Think of a top performing SE executive who you have worked with, or for. What do you remember most about how they behaved and the impact that behavior had on the organization’s goals?
4. Think of a top performing SE executive who you have worked with or for, what do you remember most about how they behaved.
5. In what ways, if any, did these behaviors impact the organization’s goals?
6. What do you think are the differences between your behavior as an SE on a project and you as a SE executive?
7. What distinguishes a SE executive from other NASA executives?
8. When you think of someone who failed as a SE executive, what was missing/ different about that person?
9. Describe what goes on in your mind when you are problem solving.
10. Has this changed since you became an executive?
11. Describe top performing executive SE’s in behavioral terms?

Figure 1. Executive interview questions.

[1] Systems orientation implies the active use of systems engineering principles and processes.

The shadow process included a minimum of one day of shadowing executives performing their day-to-day activities. In addition, study team members were invited to meetings and events that executives were either leading or participating in. The events observed included, but were not limited to, staff meetings, program, project or technical reviews, one-on-one discussions, brainstorming sessions, press interviews, and strategy meetings.

Figure 2 shows process highlights. The study team transcribed interviews, compiled results, and analyzed them for common themes, identifying elements of each theme and associated representative observable behaviors and attributes. The Chief Engineer then sent draft results to interviewees for validation and verification.

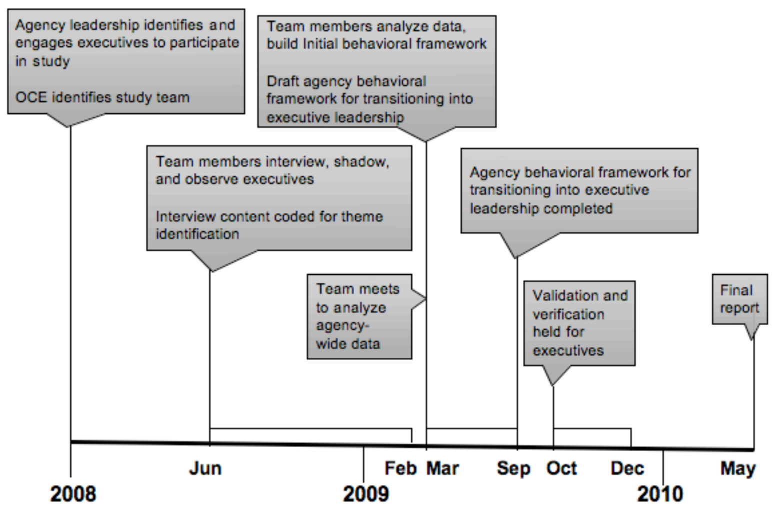

Figure 2. Executive behavior study milestones and time line.

3.2 Executive Leadership at NASA: Developing A Behavioral Framework

The data, observable behaviors/attributes that two or more executives exhibited or reported, were aggregated into elements and themes as indicated in Table 1.

Table 1 Structure -- Behavioral Framework for Executive Leadership at NASA

Level	Description	Example
Top: Themes	Collections of elements	Leadership
Middle: Elements	Aggregations of related representative observable behaviors	Manages At the appropriate level
Lowest: Representative Observable Behaviors	Behaviors/attributes that more than one senior executive exhibited or reported	Makes executive-level decisions, but delegates problem solving to the appropriate functional teams and system owners.

Table 1. Descriptions and examples of themes, elements, and observable behaviors.

4.0 Agency Findings

This study focused on determining behaviors and attributes of highly effective executives who were at one time technical managers, and its purpose was to identify those behaviors and attributes that enable individuals to be successful executives within the agency. The behaviors/attributes exhibited by the 14 participating NASA executives fell into six broad themes—leadership, attitudes and attributes (including executive presence), communication, problem solving and systems thinking, political savvy, and strategic thinking—with associated elements and representative observable behaviors.

4.1 Prevailing Themes

Study findings reinforced and extended those of the *NASA Systems Engineering Behavior Study*. Data gathered to answer the question "What are the behaviors and attributes that enable individuals to become successful executives at NASA?" clustered into elements within six broad themes. Four of these—leadership, attitudes and attributes, communication, and problem solving and systems thinking—were among the five broad themes identified in the earlier study. The earlier study also included the theme of technical acumen. In this study, executive presence emerged as a sub-theme within attributes, and two new theme, political savvy and strategic thinking, surfaced. While participating executives at NASA centers and headquarters shared common sets of behaviors around all themes, team members noted some differences in behaviors related to communications and political savvy.

The sub-themes and elements within each theme provide a broad perspective on the behaviors and attributes of highly effective NASA executives for those who wish to transition to these roles.

Leadership

Highly effective NASA executives focus on the organization and its people. Executives create organizational structures to support mission success, defining roles and responsibilities and identifying resources needed to achieve mission objectives. As they make executive-level decisions, they draw on others' expertise and involve them in the process; they delegate and facilitate the work of others, and inspire and motivate them by challenging and holding them accountable. Facing adversity they remain flexible and responsive. Identifying critical decisions, they act decisively.

These executives report levels of self-awareness, recognizing their strengths and limitations, and acknowledge that they have blind spots or biases. Acting proactively, they continuously develop themselves. They are able to let go of current roles and prepare themselves to act in new ones.

Attitudes and Attributes

Core attributes include being inquisitive, curious, patient, and organized. Examples include having a passion for learning and remaining open-minded when being presented with new approaches or strategies. They are able to manage large, complex projects.

Participating executives also exhibited “executive presence,” displaying self-confidence and courage when dealing with difficult issues. They remain calm under pressure, for example, maintaining a positive attitude when dealing with setbacks. Aware of how their personal presence and behavior affect others, they act to create safe, open environments.

Communication

NASA’s highly effective executives master communication skills. Communicating throughout the organization, and in some cases to Congress or other government agencies, executives tailor messages for different audiences using stories, analogies and the languages of specific technical disciplines. They practice effective speaking and listening skills, ensuring that meanings are clear and unambiguous. They use humor to build rapport and may make self-effacing statements to put others at ease.

Executives communicate strategically and collaboratively. Linking people, organizations and ideas, they build consensus by encouraging participation and dialogue, seeking expert opinions, and constructing internal and external networks. They use multiple approaches and communication channels and listen to different perspectives. These executives make themselves accessible to others, answering questions and discussing key issues and concerns. They set aside time to meet with others and ensure that they know it is okay to “drop by.”

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Problem Solving and Systems Thinking

These highly effective executives take a systems view of their work. For example, they are able to examine a problem from multiple perspectives and look deeply at specific issues while remaining focused on the big picture. They understand how a system works, what it is designed to do, and its functions and requirements.

Highly effective executives facilitate trades to find the right design balance between performance, cost and schedule. These executives are able to analyze a system’s data and to trace implications of a problem in a sequential manner. They recognize what is technically right among many good ideas by using systems thinking skills to compare designs.

Highly effective executives also spend time up front to identify and frame core issues and problems, then actively probe for information and insights that will reveal connections and patterns across the system. Able to deal with and assimilate large amounts of data, they validate facts and question assumptions. Considering all options before deciding, they identify and assess risks and work to remove uncertainty. Remaining open-minded and objective, they use creativity and draw on past experience to solve problems.

Political Savvy

NASA's highly effective executives know how the political system works—who makes decisions, when they make them, and what they need. They have political staying power and are able to maintain momentum over multiple years and administrations. These executives represent or promote NASA's programs in dialogues with employees and external stakeholders across the political spectrum, communicating how programs meet needs, noting consequences and implications of decisions, and, if necessary, quickly informing the Administration and/or Congress when there is a problem. Executives manage multiple demands and opportunities involving internal and external stakeholders, and consider impacts on internal and external organizations before making decisions. They are able to use a historical perspective and lessons learned to provide context for decisions and actions.

Strategic Thinking

Highly effective executives maintain an agency-wide view, keeping the big picture in mind, ensuring that NASA has a plan for maintaining competencies and capabilities needed to be successful, and balancing decisions across portfolios, programs and projects. These executives manage both mid- and long-term goals, and understand the implications of activities at multiple levels. They seek to build and maintain national and international connections and partnerships, and monitor multiple environments to understand issues or priorities that will affect agency goals and missions. They also build informal networks to gather and validate information from multiple sources. To accomplish goals, they connect organizations and individuals that might otherwise remain isolated.

4.2 Myers-Briggs Type Indicator (MBTI) and Temperament Results

Description of MBTI

The Myers-Briggs Type Indicator (MBTI®) was administered to 34 of the 38 systems engineers who participated in the first behavioral study in order to identify their personality or psychological type. In this study 10 of the 14 executives who participated provided MBTI information. Based on David Keirsey's work on Temperament®[2], the MBTI results can be broken down into one of four temperaments: Intuitive-thinking (NT), Sensing-Judging (SJ), Sensing-Perceiving (SP) and Intuitive-Feeling (NF).

MBTI and Temperament Results

See Tables 2 and 3 for information about MBTI results for both studies. The first study population had 19 NTs (56%), 9 SPs (26%), 5 SJs (15%), and one participant with the NF (3%) temperament. In this study 8 of 10 respondents were NTs (80%); the other two were SJs. In addition, while the first study contained almost twice as many respondents who were introverts (22) than were extroverts (12), in this one, 6 of the 10 respondents were extroverts.

Kiersey posited that NTs, intuitive thinkers, possess a problem solving temperament, particularly if the problem has to do with the many complex systems that make up the world around us. While neither survey group is considered large enough to draw any specific conclusions or statistical inferences from this MBTI data, future studies exploring relationships among executive effectiveness and demonstrated behaviors and

[2] For information see: http://www.keirsey.com/handler.aspx?s=keirsey&f=fourtemps&tab=1&c=overview

attributes might benefit from this information about the personality temperaments of highly successful executives at NASA.

Table 2 Agency-wide Systems Engineering MBTI® Scores by Temperament

Temperaments	# By Category	% Of Total
NT (Intuitive / Thinkers)	**19**	**56%**
INTJ	6	
INTP	8	
ENTJ	1	
ENTP	4	
SP (Sensing / Perceiving)	**9**	**26%**
ISTP	3	
ESTP	5	
ESFP	1	
SJ (Sensing / Judging)	**5**	**15%**
ISTJ	3	
ISFJ	1	
ESFJ	1	
NF (Intuitive/ Feeler)	**1**	**3%**
INFJ	1	

Table 2. Scores of 34 of the 38 highly regarded systems engineers selected to participate in the *NASA Systems Engineering Behavior Study.*

Table 3 Snapshot of Highly Effective Executives' MBTI® Scores by Temperament

Temperaments	# By Category	% Of Total
NT (Intuitive / Thinkers)	**8**	**80%**
INTJ	2	
INTP	1	
ENTJ	3	
ENTP	2	
SJ (Sensing / Judging)	**2**	**20%**
ISTJ	1	
ESFJ	1	
ESFJ	1	

Table 3. Scores of 10 of the 14 highly effective executives selected to participate in this study, *Executive Leadership at NASA: A Behavioral Framework.*

4.3 Themes, Elements and Representative Observable Behaviors

See Table 4 through Table 9 for detailed descriptions of themes, elements and representative observable behaviors.

Table 4 – Leadership Theme

Elements	Representative Observable Behaviors/Attributes
Creates Organizational Infrastructure	• Identifies the specific combination of skills, talents, and technical competencies required to achieve mission success. • Defines the roles and responsibilities of team members. • Assigns roles and responsibilities and evaluates performance based on team members' current capabilities and prior work experiences. • Designs and implements standard operating procedures that enable a smooth, consistent, and coordinated workflow.
Gauges Resource Needs to Achieve Mission Objectives	• Identifies human, financial, and material resource requirements in consultation with subject matter experts and project owners. • Ensures that mission goals and outcomes are achievable given available resources.
Manages a the Appropriate Level	• Makes executive-level decisions, but delegates problem solving to the appropriate functional teams and system owners. • Enables others to get work done. • Holds others accountable for their assigned deliverables. • Gathers information from stakeholders and experts at all levels when making decisions that can only be made at the executive level. • Sets the context for decisions—the "what" and the "how."
Accepts Change and i Resilient	• Demonstrates flexibility and responsiveness to changing priorities and critical needs. • Monitors the environment for changes in required outcomes, critical assumptions, available resources, or other factors that could necessitate a change in strategy. • Adjusts direction, strategy, roles responsibilities and/or schedule to ensure critical organizational needs are met.
Acts Decisively	• Identifies decisions that are critical, non-critical, and important to avoid. • Identifies and puts parameters around the amount of information needed to make a given decision. • Makes timely decisions based on experience, resource constraints and available information.
Inspires and Motivates Team Members to Perform at Peak Performance	• Encourages team members to accept new challenges and perform to the best of ability in finding solutions to seemingly insurmountable problems. • Promotes creativity and intelligent risk-taking. • Challenges others to ask questions and think "outside the box." • Helps team members maintain a positive attitude and forward progress toward goals and outcomes when facing adversity while acknowledging threats and challenges. • Monitors, tracks and communicates progress. • Evaluates strategies on the basis of outcomes. • Publicly acknowledges team members' accomplishments and areas of expertise. • Provides informal praise (verbal, email, thank you card, etc.) of individual and group accomplishments. • Provides appropriate formal reward and recognition for good performance.

Table 4 – Leadership (cont.)

Elements	Representative Observable Behaviors/Attributes
Builds Trust and Respects Confidentiality	• Trusts others' expertise and judgment. • Reevaluates assumptions, judgments, and strategies based on input from subject matter experts and stakeholders. • Designs and implements communication processes that ensure the fair and objective evaluation of ideas and opinions. • During individual and group discussions, identifies proprietary informatio and reaches agreement with participants on how the information should be managed.
Develops Employee Capabilities	• Provides resources, visible support and encouragement to employees to develop knowledge, skills, an competencies. • Identifies and encourages employees with talent, potential and the ability to take a system-wide view to problem solving. • Provides employee work assignments and training opportunities that address critical developmental needs. • Meets privately with employees to review performance an discuss work strategies. • Provides employees constructive feedback on performance by exploring employees' thought and decision-making processes and helping them discover insights. • Delivers corrective feedback on individual performance privately, and in a manner that is objective and non-judgmental.
Reduces Distractions	• Deals personally with issues and problems that would otherwise be a source of distraction to project team members. Asks team members, "How can I help? What is getting in the way of your work?" • Negotiates on time and resource issues on behalf of project team members.
Aware of Self and Values	• Knows personal strengths, limitations and motivations. • Knows when others need to be consulted. Understands that "getting it right" is always more important than "being right." • Is aware that blind spots or biases might exist in own thinking and asks others to keep him aware of other perspectives. • Adheres to a strong set of values that align with Agency's mission and purpose. • Articulates values so other understand one's perspectives and positions.
Develops Self	• Maintains basic working knowledge of technical disciplines. • Maintains contact with current engineers and engineering projects. Seeks opportunities to interact with them and perform limited 'hands-on' work. • Conducts benchmarking of engineering organizations performing cutting-edge engineering work and asks, "How do they do that?" • Judiciously learns what is required in each new position and what it takes to be successful government executive. Talks to and observes those who do the job best. • Develops a learning plan to gain the knowledge, skills and abilities needed to be successful at each new level.
Lets Go of Current Role to Prepare for New One	• Intentionally chooses to move into leadership and stop being technical expert. • Willing to relinquish familiar job functions and develop skills and knowledge necessary to grow and advance to the next level of leadership.

Table 5 – Attitudes and Attributes Theme

Elements	Representative Observable Behaviors/Attributes
Remains Inquisitive and Curious	• Has an ongoing passion for learning, enhancing knowledge, skills, and experience in both technical and non-technical subjects. • Participates in wide variety of formal and informal learning opportunities. • Continually asks questions and probes for information.
Is Patient	• Understands that high-performing social and technical systems take time to develop. • Manages and oversees key system functions, but allows other elements of the system t evolve and stabilize over time. • Maintains commitment to chosen path or strategy, even when long-term results are not yet evident. • Is patient and open-minded when presented with new approaches or problem-solving strategies.
Is Organized	• Can manage large and complex systems, process extensive amounts of data, and rapidly explore the costs and benefits of number of alternative strategies. • Effectively compartmentalizes, prioritizes, schedules, delegates, completes, and evaluates the outcome of activities associated with the executive role. • Makes full use of IT tools and technologies to help organize calendar and decisions.
	Executive Presence
Displays Self-Confidence and Courage	• Exhibits confidence in technical knowledge, skills, and ability to lead and achieve goals. • Identifies the difficult issues, e.g., “the elephant in the room.” • Willing to be controversial. Fearlessly questions decisions even when in the minority or standing alone. Willing to disagree or push back on senior leadership. • Willing to make difficult decisions by listening to others and then act as final arbiter.
Remains Calm under Pressure	• Manages organizational pressures while maintaining team and organizational momentum by identifying the difficult issues and focusing on the solution. • Maintains perspective and a positive attitude in the face of adversity and avoids being defeated by setbacks by focusing o solutions. Holds the belief that "we will get past the problem, in the best way possible, to achieve the greater good.”
Aware of How Personal Presence and Behavior Affects Others	• Maintains a high degree of physical energy throughout the day. • Walks in with a no-nonsense style, e.g., “We have a job to do. Let's not waste time. “ Friendly, but to the point. • Aware that others will tend to defer based on executive’s position. Encourages others to state opinions in order to get the best solution. • Creates a safe environment that helps others feel comfortable by, for example, shaking hands, smiling, addressing people by their first names, referring to their previous work, showing humility, letting others take the lead, and engaging others by asking questions.

Table 6 – Communication Theme

Elements	Representative Observable Behaviors/Attributes
Communicates throughout the Organization	• Ensures important information is communicated to stakeholders throughout organization. • Communicates downward and laterally by disseminating information o priorities, interdependencies, impacts, and lessons learned. • Communicates appropriate amount and type of information upward. • Where appropriate, helps individuals and organizations gain access to information needed to perform their work effectively.
Tailors Messages	• Understands how different audiences interpret information. • Expertly tailors and delivers messages to meet the needs of specific audiences such as the media, Capitol Hill, or other key stakeholders. • Can speak the language of multiple disciplines, i.e., finance, personnel, legal, etc. Consciously and continually learns to communicate with representatives from all functional areas. (**HQ**) • Knows how to translate information on complex technical programs into non-technical language. Talks to a congressional staffer in the language of Congress; talks to OMB staff in the language of the budget, etc. **(HQ)** • Uses audience appropriate analogies from discipline when speaking to engineers and analogies from home and office when communicating with non-technical people.
Strives for Clarity	• Realizes that clarity is critical to providing facts in a way that ensures that understanding is reached. • Uses clear language to be sure everyone knows what is meant and has a shared understanding. • Compares and contrasts ideas, e.g., "if this then … if that then." • Summarizes decisions and agreements at meetings. • Practices active listening. Solicits feedback to check that others receive messages that were transmitted. May ask staff to repeat in their own words what was said. When person is more senior, may check with that person's staff to ensure receipt of intended message. **(HQ)** • Aligns verbal and non-verbal messages to ensure the meanings are clear and unambiguous Ensures consistency between written charts and verbal communications. • Makes certain that meeting formats are consistent with their purpose, e.g., brainstorming, working an issue, information sharing, decision-making, etc. Ensures those in attendance know why they are there.
Assesses Context	• Knows when and how often to communicate. Assesses the context before speaking. Senses others' need to argue a point, vent a frustration, solicit feedback, etc., and responds accordingly. • Knows what is the right level of communication for each situation. Strikes the right balance in communicating what is needed, but not more.

Note: Behaviors observed only in executives located at Headquarters are noted by **(HQ).**

Table 6 – Communication (cont.)

Elements	Representative Observable Behaviors/Attributes
Uses Humor	• Uses humor to build rapport with individuals and groups and to reduce fear and anxiety among team members. • Keeps the atmosphere light as appropriate when dealing with difficult or challenging issues. • May joke, share personal or humorous anecdotes or make self-effacing comments during or starting meetings. • Smiles and remains energetic, animated and attentive during discussions.
Practices Effective Speaking and Listening Skills	• Continually demonstrates effective speaking and listening skills (e.g., turn-taking, paraphrasing, asking questions, etc.) to ensure a productive exchange of information and ideas. • Listens effectively and gives individuals full attention. Ends conversations with a summary of actions, due dates, and who is responsible. • Sits back and lets the debate happen. Listens to all the various perspectives and then takes action. • Mentors others to help them become better communicators. Explains how others could potentially misinterpret an imprecise statement.
Communicates Through Story Telling and Analogies	• Uses personal experience, organizational stories and analogies to explain challenges, issues and situations. • Uses historical references (e.g., Lewis and Clark and their scientific and research goals). • Discusses the history of NASA (e.g., how the field centers came into being) to illustrate the importance of cultural differences an approaches.
Links People, Organizations and Ideas	• Makes transition from a program- or project-level systems engineer who concentrates on how technical systems interface to an executive who focuses primarily o how to get people to connect and work effectively together. • Establishes common infrastructure and provides necessary resources. • Conducts effective meetings. Knows who should be at meetings (individuals/ groups) and inquires about those who are missing. Avoids making final decisions until key stakeholders are available. • Uses a variety of communication channels to maintain contact with individuals/groups throughout the day. Will track down experts mentioned in meetings to get their opinion on an issue. • For important decisions requiring consensus, asks each stakeholder to confirm support and/or present objections until consensus is reached.
Encourages Participation	• Uses facilitation, coaching, and dialogue skills to ensure all opinions are solicited, points of view are shared and everyone has the opportunity to participate. • Asks open-ended questions, e.g.," What do you think?" vs. "Do you agree or disagree? • Uses authority (positional, expert, etc.) to facilitate the structure and flow of meetings to provide opportunities for all to participate. • Senses when opinions are being suppressed; takes steps to solicit that input. • Avoids overusing email or any one mode of communication.

Table 4 – Communication (cont.)

Elements	Representative Observable Behaviors/Attributes
Seeks Expert Opinion	• Willing to admit what one does not know and seek out technical experts for their opinion. Openly says, "I don't know." • Intentionally identifies and builds networks of experts to call on. Takes time to determine the best expert for a particular problem. • Provides approaches, ideas, and strategies to help others reach their goal but leaves the decision to those responsible. Does not dictate solutions.
Builds Consensus	• Connects people, organizations, and ideas to build shared understanding and consensus by ensuring participation and buy-in. Ensures all stakeholders participate. • Facilitates discussion. Listens to different perspectives and ensures everyone is heard. Will restate or rephrase a point someone has made to ensure that everyone understands what was said. • Keeps the conversation going until there is convergence of ideas. • Does not assume understanding. Summarizes agreements and ensures they are communicated. • Looks for common, unifying goals. Integrates perspectives into the big picture. Openly and honestl explains the rationale for moving in a given direction. • Strategically builds and utilizes formal and informal networks.
Builds Relationships through Interaction	• Enjoys interacting and working with other people. Has very good interpersonal skills. • Uses "We need to …" to correct someone versus "You need to"… (**HQ)** • Devotes a portion of conversations to non-work issues. • Stays focused on the individual/speaker and shows genuine interest. • Rarely holds side conversations or lets blackberry be distractive. • Strives to end meetings and conversations on an upbeat/positive note.
Demonstrates Accessibility	• Expresses availability to discuss issues, questions and concerns. • Has a strong focus on schedule and being available for important events. **(HQ)** • Gives people the time they need to explain the issue, tell their story, etc. Does not rush others. Does not show impatience. Willing to engage in hallway or parking lot conversations. • Includes staff in meetings. Ensures anyone who wants to be included is included. • When issues are brought up, ensures actions are taken to address them. • Makes room on calendar to meet with others. Finds "15-minutes on calendar" for same day meetings. Allows for drop-ins and responds positively. Creates a climate where people feel they are allowed to "drop by."

Note: Behaviors observed only in executives located at Headquarters are noted by **(HQ).**

Table 7 – Problem Solving and Systems Thinking Theme

Elements	Representative Observable Behaviors/Attributes
Uses Systems Perspective	• Uses systems thinking in strategy development and to see entire Agency-wide system. • Applies systems engineering principles to mission/programs that have significant political, social, and economic implications. • Applies a systems perspective in the performance of executive roles and responsibilities.
Thinks Systemically	• Can look at a problem within multiple frameworks (e.g., 'change of variables'). • Able to look deeply into a problem while remaining focused o the big picture. Sees the big-picture while demonstrating an overall awareness of the details. • Able to look at all the pieces individually and collectively to meet program, mission and agency-wide needs, and to identify gaps and overlaps/duplications. • Sees multi-view representations of systems to understand how the pieces fit together and interact. Visualizes systems in 3-D. Draws a picture in the mind or on paper. • Focused on developing system that meets end-item product objectives and successfully integrates the systems pieces into the whole. • Understands how the system works, what it was designed to do, its functions and requirements. • Looks across the entire system and facilitates trades and compromises to get a balanced design. • Recognizes what is technically right among many good ideas by viewing problem across system boundaries and comparing each design to the other. • Thinks about how components were designed to interact and what other interactions could occur that were not considered in the design. • Is able to analyze the system's data. Traces implications of a problem in a step-by-step manner across the system. • If having difficulty understanding a scenario finds a different vantage point that offers fresh perspective.
Identifies and Defines Core Issues/ Problems	• Spends time u front to ensure that he and others understand, frame and define the problem. • Identifies the real issue /problem (whether technical, infrastructure, administrative, executive resource, or other) by asking questions and identifying the key requirements. • Confirms that the problem is identified. (For example, asks: "Are we solving the right problem?" "Has the correct problem been identified?" "Have we defined the problem properly?" "Do we understand the problem?" "Do we understand the constraints?")
Activel Probes for Information and Understanding	• Seeks to understand all aspects of a challenge. • Probes for crucial and critical information that may be missing. • Considers all proposed solutions/perspectives before making a decision. • Continues to question thinking and extract data until all issues have been addressed and there is shared understanding. Asks questions such as: "What is the measure of goodness?" "What has not been looked at?" "Why?" "Does it still make sense?"

Table 7 – Problem Solving and Systems Thinking (cont.)

Elements	Representative Observable Behaviors/Attributes
Finds Connections and Patterns cross System	• Examines and explores the implications of how technical decisions will affect the larger system architecture. • Observes system interfaces and the ripple effect of how changing requirements or how making a changes to one element will affect other elements or the system. • Locates and corrects sub-system 'disconnects' or 'inconsistencies' that are having a negative impact o system performance.
Assimilates, Analyzes, and Synthesizes Data and Information	• Approaches and solves problems in a systematic manner by using tools, processes, procedures in order to find solutions. • Ensures decisions made are supported with data. Assimilates and distills large quantities of data from across the organization an ensures all of the data is o the table to solve a problem or make a decision. • Breaks data into smaller pieces or parameters, prioritizes, then synthesizes to reach an answer or solution. • Determines how to put together all available information in a way to rigorously test mathematically or physically that the problem is adequately understood.
Validates Facts, Information and Assumptions	• Questions all assumptions that go into a design. • Anticipates and looks for problems or issues in the system. Knows where data is missing/needed. • Recognizes that seemingly minor miscalculations can lead to significant problems in system performance. • Identifies system elements that lack metrics or have metrics that are misleading. • Recognizes data has limitations and does not rely o it as the only source of information.
Considers All Options before Deciding	• Works to understand a problem from all perspectives. Actively seeks and weighs different perspectives Open and willing to listen to multiple views. • Is highly inclusive, drawing on the full knowledge, skills, and experiences of the organization. • Considers all types of costs (e.g., technical, schedule, political, human, financial). • Identifies what will enable or inhibit the ability to accomplish goals. Looks at all aspects of the organizational system, e.g., facilities, budgets, policies, procedures, etc. Asks: "What would happen if I did nothing?" "What is the worse thing that could happen?" • Understands there is always more than one solution. • Comes u with several solutions, defines consequences of each and relates impacts to managers and employees.
Identifies, Assesses, and Manages Risk	• Understands that managing risk is an ongoing process. Asks probing questions to ensure risks have been adequately explored. • Uses past experiences to anticipate potential problems that may impact system. Identifies worst-case scenario and works from that point back. • Focuses on identifying and assessing risks by creating plans for dealing with those risks effectively. Identifies key indicators and methods of testing for each type of problem. • Applies and demands sufficient rigor in the application of analytical processes. • Develops mitigation strategies for addressing problems, should they arise.

Table 7 – Problem Solving and Systems Thinking (cont.)

Elements	Representative Observable Behaviors/Attributes
Acknowledges and Manages Uncertainty	• Works to remove as much uncertainty as possible by questioning everything. • Analyzes failures (what went wrong) and successes (what went right). • Ensures lessons learned are captured. • Lets others know of own willingness to be comfortable with uncertainty. • Openly and honestly discusses personal and programmatic successes, failures, an lessons learned.
Remains Open-Minded and Objective	• Receptive to hearing diverse and dissenting opinions. Is willing to re-think/re-work an issue or to change direction when new information or a better idea is presented. • Evaluates decisions objectively. Maintains flexibility by avoiding attachment to a particular strategy or point of view.
Uses Creativity in Solving Problems	• Possesses passion for problem solving and takes initiative to solve problems. Enjoys and is energized by fully concentrating on a problem for long stretches, until solutions are formed and implemented. • Does not adhere to rigid rules or formulas for system design, but may create new ideas and approaches that are necessary to deal successfully with system constraints. • May use intuition and past experiences to solve problems. Supplements traditional problem-solving strategies with those that are creative and non-linear.
Draws on Past Experience	• Knows good intuition is based on experience and works to expand that experience. • Uses experience, history, intuition, and sensing to assess situations and develop solutions. • Draws on past successes and failures to develop the proper approach. Knows when something looks right. • Solves problems with balance of innovative developments and prove heritage products. May rely o experience and existing design as guides, but sees each opportunity as a canvas to design new solutions.

Table 8 – Political Savvy Theme

Elements	Representative Observable Behaviors/Attributes
Knows How the Political System Works	• Knows who makes decisions and what they need. Keeps up to date with new Members of Congress and staff and relies on NASA's Congressional experts to represent the agency in the best light. **(HQ)** • Has a keen sense of timin when opportunities arise. Understands how some opportunities are short lived and quick action is needed. • Knows how to present design to show near-term gains that will meet current Administration and Congressional goals, while building o a longer-term accomplishment that might be realized over number of Administrations.
Has Political Staying Power	• Able to maintain momentum over many years and several Administrations. Quickly learns the priorities of new Administrations and effectively communicates how NASA is meeting those needs. • Assesses the current political agenda to determine the likelihood of obtaining the budget needed. Assesses the political and budget realities in context of the design, requirements, and potential trades.
Represents/ Promotes NASA Programs across the Political Spectrum	• Understands and effectively communicates with government leadership on how programs meet agency and national needs. **(HQ)** • Explains consequences and implications of NASA decisions and how the Administratio and Capital Hill may interpret the agency's actions. Helps others understand what the Administration is looking for so they can work more effectively within those constraints. **(HQ)** • Explains the probable reactions of NASA's stakeholders to decisions that are made or put o hold. • Responsive to upper management's needs. Sends notes, calls and updates as activities occur and issues emerge. • Meets commitments in order to gain credibility and trust. Only makes commitments that NASA can meet. • Lets Administration/Congress know when problems arise notifies them early. **(HQ)**
Manages Multiple Demands/ Opportunities	• Balances the needs and political interests of internal and external stakeholders, weighing what is best for the program with what is best for the agency Makes decisions based o what is best for both. • Considers impacts of executive decisions and actions o organizations inside and outside of NASA before taking action. • Continually monitors these decisions and makes course corrections to meet high priority goals and objectives. • Asks, "What is my boss and what is the Administration worried about?" • Is aware of what is important to the NASA Administrator and other key players, and keeps them informed.
Provides a Historical Perspective	• Knows it is important for those inside and outside the agency to know NASA's history. • Helps others see and understand the historical progression of strategies and decisions. Is mindful that NASA has a wealth of lessons learned and is always working to ensure that the agency does not repeat mistakes.

Note: Behaviors observed only in executives located at Headquarters are noted by **(HQ).**

Table 9 – Strategic Thinking Theme

Elements	Representative Observable Behaviors/Attributes
Maintains an Agency-Wide View	• Ensures that NASA has plan moving forward to maintain both the competencies and capabilities needed to be successful. • Intentionally selects people with different perspectives, talents and knowledge to form a strong management team. • Assimilates large amounts of information from across the agency. Makes decisions by keeping the big picture in mind. Considers all perspectives and proposed solutions before making a decision. • Decisions are balanced across programs and projects. • Works the larger agency-wide "trade space" to meet NASA's and the nation's highest priorities. Trades are made across missions and/or centers and may involve negotiations across federal agencies.
Manages Near-Term and Long-Term Goals	• Keeps the end state in mind while managing day-to-day activities. • Continually looks at near-term activities and assesses how they may impact long-term results. • Proactively anticipates and positions the organization years in advance. Focuses o five years and beyond. • Sets path and has the ability t stick to that path for the extended period of time. • Is mindful of the critical timing of issues (e.g.," We have 12 hours to make this decision."). Will sometimes define decisions in terms of "shelf-life."
Understands Broad Implications of Activities at Multiple Levels	• Understands where NASA's mission connects to the missions of other federal agencies and foreign nations. Considers them potential partners, collaborators and in some cases customers. • Seeks to build and maintain connections and partnerships. Shares information and communicates on shared goals and projects.
Monitors the Environment	• Monitors the environment outside NASA to understand national and international priorities and issues that will impact agency goals and missions. • Works to understand larger government-wide issues and problems and find ways in which NASA's work can help solve these issues and problems. • Works with other federal agencies to leverage overall federal program investments (e.g., maturing another agency's technology fo use in NASA's programs).
Uses Networks	• Builds and uses informal networks to validate and gain additional information. • Looks to many different sources to be sure issues are covered and there are no surprises. • Connects organizations and individuals that need to be connected to accomplish goals. • Probes and tests assumptions by reaching out to individuals on the periphery. Uses the "fringe" (individuals outside of a program or project team but aware of issues and able to lend support) to gain information, test assumptions, and assess the size and scope of issues and problems.

5.0 Summary and Conclusions

The 14 NASA executives interviewed and observed for this study, *Executive Leadership at NASA: A Behavioral Framework,* exhibited a common a set of specific behaviors and attributes that were instrumental to their success. These behaviors and attributes are observable and measurable and are similar to those demonstrated by highly successful systems engineers (as described in the 2008 *NASA Systems Engineering Behavior Study).*

The collection of behaviors and attributes demonstrated by these successful NASA executives fell into six broad thematic categories. Four of these—leadership, attitudes and attributes, communication, and problem solving and systems thinking—were among the five top themes identified in the earlier study of systems engineers. In this study executive presence emerged as a sub- category within attributes and attributes. Two new themes—political savvy and strategic thinking—were unique to executives. Also noted were some differences in communication and political savvy behaviors exhibited between NASA center and headquarters executives.

The study revealed that highly successful executives possess a foundation of technical knowledge in one or more disciplines. At the executive level, breadth of knowledge across technical disciplines is a greater asset than depth of knowledge in a single discipline. As was the case for highly successful systems engineers, technical knowledge provides an essential footing, but the less definable skills in leadership, communication, problem solving and systems thinking set these individuals apart. Attributes such as being curious, inquisitive, patient and organized are also potential indicators of success.

Executive presence is an essential part of leadership at the executive level. For example, participating executives display self-confidence and courage in dealing with difficult issues, and remain calm under pressure. Aware of how their personal presence and behavior impact others, they take steps to create safe, open environments.

Political savvy and strategic thinking also become critical. NASA's highly effective executives know how the political system works—who makes decisions, when, and what they need. They have political staying power and are able to maintain momentum over multiple years and administrations. Highly effective executives maintain an agency-wide view, keeping the big picture in mind, and manage both mid- and long-term goals. They build formal and informal networks to validate and get additional information, and to make necessary connections among organizations and individuals to accomplish goals.

The study yielded valuable information regarding NASA leadership behaviors, and will serve as a basis for further investigation. Future explorations could benefit from: a) having a larger and broader sample, b) more hours of observation, c) possible inclusion of women and minorities, and d) interviews with other personnel in an executive's inner circle.

Executive Leadership at NASA: A Behavioral Framework provides a basis for individual and organizational action. On an individual level, employees can use the findings to help build and structure their career choices and developmental options. An awareness of the behaviors and attributes of highly successful executives will allow technical managers and their coaches and mentors to make more effective choices in building their development strategy.

On a discipline level, this study provides the Office of the Chief Engineer with a specific, behavioral framework that will allow it to create learning approaches and strategies that strengthen executive development across the agency and build more targeted programs and policies to support mission success.

Since the behaviors and attributes of highly successful executives are consistent with those of highly regarded systems engineers, the behaviors prescribed for technical managers do not need to be unlearned in order to transition successfully to the executive level; rather, employees can build upon those foundational skills.

Successful executive behaviors are mainly relational—they are broad integrative thinking competencies that can be practiced, learned and developed at any level at NASA, given the right experience and exposure. Care should be taken to avoid designating certain behaviors as exclusive for leaders or executives in a way that delays their introduction into the training and development curriculum.

NASA’s environment is constantly in flux. Complexity is increasing, and the agency’s needs and vision are changing. There are more multi-center and multi-organizational (federal agencies, industry, academia, and international partners) programs, a growing need to keep up with technical advancements, and needs for greater creativity and innovation and improved performance. Social norms are shifting as well. NASA increasingly has less hierarchy in its organizational structures, more participative leadership, greater individual responsibility, and more utilization of a virtual work environment. The next generation of executives will need to address these challenges and more.

To meet NASA’s future needs for executive leadership it essential that we begin the immediate development of behaviors and attributes that are critical to their success.

6.0 Next Steps

This study’s findings provide a firm direction to plan learning and development activities that help NASA’s high-performing technical managers successfully transition to and operate in executive roles. These findings will allow NASA to introduce targeted training and development and experiential opportunities prior to placing individuals in these critical roles, thus enabling them to develop the necessary skills over the course of their careers. The themes, elements, and representative observable behaviors provide concrete realistic examples for employees as they design their Individual Development Plans, which include hands-on learning activities, coaching and mentoring opportunities, training, formal training and knowledge sharing programs and materials.

The Academy of Program/Project & Engineering Leadership (APPEL) will:

- Evaluate NASA curriculum offerings for technical managers and executives against this study and determine how these findings can be leveraged to enhance this learning.
- Update the Systems Engineering Leadership Development Program (SELDP) design, particularly in the areas of communication, executive presence and strategy. Update SELDP selection criteria to be inclusive of additional behaviors reflected in this study.
- Review systems engineering (SE) and program and project management (PPM) curricula to assess where program offerings can be enhanced and updated.
- Seek outside speakers and benchmarks that reflect behaviors and qualities reflected in the study. Purposefully focus on these behaviors and attributes as central to the learning process.
- Add enhanced focused learning, knowledge sharing, and career development materials and activities that address how individuals can learn and develop themselves in these areas.
- Train coaches and mentors in enabling the development of these critical areas.

In addition, OCE will share these study findings widely both inside and outside of NASA. Conference briefings and articles are being developed, and this report will be posted on the NASA Engineering Network.

7.0 Acknowledgements

Many people have contributed to the success of the study and deserve recognition, including the executives who participated in this study and the team members who dedicated themselves to advancing the understanding of the "art of systems engineering."

In addition, this study would not have been possible without the support from the following people:

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8.0 Appendices

8.1 Appendix 1. Executive Interviewees

Table 10 – Names of NASA Executives Interviewed at Each NASA Center

Center*	Interviewees	Current Position
GSFC	Rick Obenschain	Center Director, Goddard Space Flight Center
	George Morrow	Director, Flight Projects, Goddard Space Flight Center
HQ	Mike Griffin	Former NASA Administrator. Currently Eminent Scholar and Professor Mechanical and Aerospace Engineering University of Alabama Huntsville
	Chris Scolese	NASA Associate Administrator
	Mike Ryschkewitsch	NASA Chief Engineer
	William Gerstenmaier	NASA Associate Administrator for Space Operations
JPL	Brian Muirhead	Constellation Program Chief Architect Chief, Systems Engineering & Integration Design Integration Office
JSC	Mark Geyer	Program Manager, Orion Manager, Johnson Space Center
	Michael Suffredini	Program Manager, International Space Station, Johnson Space Center
LaRC	Stephen Jurczyk	Deputy Director, Langley Research Center
	Ralph Roe	NASA Engineering and Safety Center, Langley Research Center
MSFC	Steve Cook	Manager, Ares Project Office, Marshall Space Flight Center
	Daniel Dumbacher	Director, Engineering, Marshall Space Flight Center
Retired	John Muratore	Retired from NASA. Currently Associate Professor Aviation Systems and Flight Research Program, University of Tennessee Space Institute.

* Center Acronyms in Table 10.

GSFC Goddard Space Flight Center
JPL Jet Propulsion Laboratory
JSC Johnson Space Center
LaRC Langley Research Center
HQ NASA Headquarters
MSFC Marshall Space Flight Center

Memorandum of Understanding for Temporary Assignment at the Jet Propulsion Laboratory of NASA Employee Under NASA's Systems Engineering Leadership Development Program

I. Purpose

This Memorandum of Understanding ("MOU") is entered into by the National Aeronautics and Space Administration ("NASA") and the California Institute of Technology ("Caltech"). The MOU establishes the terms and conditions for the temporary assignment of NASA employee (***NAME OF NASA EMPLOYEE***) to the Jet Propulsion Laboratory ("JPL") for a period of (***LENGTH OF ASSIGNMENT***). Actual work experience will not exceed (***LENGTH OF ASSIGNMENT***). The authority for this MOU is 5 U.S.C. 4101 et seq., the Government Employees Training Act of 1958, as amended and 42 U.S.C. 2473 et seq., the National Aeronautics and Space Act of 1958, as amended.

The Jet Propulsion Laboratory, run by a division of Caltech, is located at 4800 Oak Grove Drive, Pasadena, CA 91109. National Aeronautics and Space Administration Headquarters is located at 300 E Street, S.W., Washington, DC, 20546.

II. Background

As part of NASAs Systems Engineering Leadership Development Program ("SELDP"), participants engage in outside temporary work assignments in order to broaden their knowledge and increase their leadership skills. A temporary assignment to Caltech/JPL has been identified as a valuable developmental opportunity for (***NAME OF NASA EMPLOYEE***). This position will enable the participant to gain new perspectives in the field of systems engineering and, at the same time, will benefit NASA by building and retaining a skilled and effective workforce. (See NPD 3410.1 for benefits to NASA).

The scope of JPL's work is defined in section C of Contract NAS7-03001 between NASA and Caltech (the "Prime Contract"). Caltech operates JPL as a NASA Federally Funded Research and Development Center to meet Government research and development needs which cannot be met as effectively by existing Government resources or normal contractor relationships. JPL has a dual character; it is a NASA-owned facility as well as an operating division of Caltech staffed with Caltech employees. JPL as an institution encompasses a full spectrum of activities from basic research through the conduct and management of space flight missions.

The NASA employee will work at Caltech/JPL at (***LOCATION WHERE THE NASA EMPLOYEE WILL WORK***) where he/she will (***NAME OF INTERNAL ORGANIZATION WITHIN JPL WHERE THE NASA EMPLOYEE WILL WORK AND A DETAILED DESCRIPTION OF THE NASA EMPLOYEE'S JOB ASSIGNMENT***). This assignment will serve as a broadening experience to enhance the employee's perspective and meet his/her developmental needs.

Caltech/JPL will serve as the sponsor for (***NAME OF NASA EMPLOYEE***) for the duration of the assignment. The sponsor will assign daily tasks to (***NAME OF NASA EMPLOYEE***) to ensure that (***NAME OF NASA EMPLOYEE***) has the opportunity to work on projects related to program goals and his/her developmental needs.

(***NAME OF NASA EMPLOYEE***) will interact with Caltech/JPL organizational staff at all levels. At the conclusion of the assignment, (***NAME OF NASA EMPLOYEE***) will prepare an SELDP Final Program Report.

III. Responsibilities

Nothing in this MOU is intended to affect, alter, or change any terms or conditions of the Prime Contract between the parties nor is this MOU intended to, in any way, affect the respective rights and obligations between the parties as set forth in the Prime Contract. To the extent there is any inconsistency between this MOU and the Prime Contract, the terms of the Prime Contract shall govern. Any effort performed by Caltech/JPL in connection with this MOU shall be performed under the Prime Contract.

It is the intent of the parties in entering into this MOU that the following efforts will be undertaken, consistent with the Prime Contract:

NASA will use reasonable efforts to accomplish the following:

1. Assign (***NAME OF NASA EMPLOYEE***) to Caltech/JPL. While assigned to Caltech/JPL and performing services pursuant to this agreement (***NAME OF NASA EMPLOYEE***), will remain an employee of NASA.
2. Retain sole responsibility for the payment of all salary, allowances, and benefits under applicable Federal law and regulations. (***NAME OF NASA EMPLOYEE***) is prohibited from receiving any payment or other compensation from Caltech/JPL, including (but not limited to) such forms of compensation as meals, housing, personal laundry, time off, etc.
3. Retain responsibility for (***NAME OF NASA EMPLOYEE***) workers' compensation benefits available for injuries arising out of the performance of his duties within the scope of this assignment. Caltech/JPL will not include (***NAME OF NASA EMPLOYEE***) under its workers compensation program.

Caltech/JPL will use reasonable efforts to accomplish the following:

1. Provide on-the-job training to (NAME OF NASA EMPLOYEE) during the term of this agreement.
2. Assign (***NAME OF NASA EMPLOYEE***) to various projects, as described in the Background Section above, during the assignment.
3. Provide (***NAME OF NASA EMPLOYEE***) with a sponsor for the duration of the assignment. The sponsor will work with (***NAME OF NASA EMPLOYEE***) to develop a general plan for the duration of the assignment which will ensure that (***NAME OF NASA EMPLOYEE***) has the opportunity to work on projects related to SELDP goals and that meet his/her developmental needs.

4. Comply with the attached "Time-Keeping, Administration and Evaluation Procedures."
5. Provide appropriate office space, administrative, and logistical support for (***NAME OF NASA EMPLOYEE***), including communications access, normal and proprietary materials, storage, clerical support, office equipment, and supplies.

Both parties will be responsible for avoiding any conflicts of interest situations and to so instruct their respective employees.

IV. Schedule and Milestones

Caltech/JPL understands that (***NAME OF NASA EMPLOYEE***) is unavailable for work assignments on the certain days due to required developmental program activities that will be specified by the SELDP Director.

V. Financial Obligations

Financial obligations are governed by the Prime Contract.

VI. Liability and Risk of Loss

Liability and Risk of Loss are governed by the Prime Contract.

VII. Intellectual Property and Export-Controlled Data

The parties do not intend that the activities performed under this MOU will result in inventions or the creation of new intellectual property, but if any result, the following will apply:

- Under Federal law, (***NAME OF NASA EMPLOYEE***) remains a Government employee during the developmental training assignment. Any intellectual property developed by the Government employee pursuant to this MOU is governed by applicable federal statutes, regulations, rules, and policies.
- Subject to the U.S. Government's rights and interests, Caltech shall retain exclusive title and all rights to inventions, copyright and other intellectual property arising from conceptions or efforts of JPL employees or consultants in performing this MOU. The U.S. Government retains a right to use such inventions, copyrighted materials, or other intellectual property, royalty-free, for authorized government purposes.
- Subject to U.S. Government rights and interests, NASA and Caltech shall hold joint title and rights in inventions, copyrights, and other intellectual property arising from the joint conceptions or efforts of both parties' employees or consultants in performing under this MOU.

In the performance of this MOU, JPL and NASA may exchange or develop data, information, software or other technology which may be subject to the export control laws and regulations of the United States, including the International Traffic in Arms Regulations (ITAR), 22 C.F.R. 120-130 and the Export Administration Act Regulations (EAR), 15 C.F.R. 730-774). The parties agree to fully comply with all such laws and regulations in the performance of this MOU and each party will be responsible for obtaining export licenses or other export authority as may be required before exporting controlled data, information, software or other technology to foreign countries or providing access to foreign persons (as defined in 22 C.F.R. 120.16).

In the event that JPL is requested by NASA to provide remote access accounts for its employees authorizing access to any JPL electronic library or server, JPL will require NASAs Export Administrator to certify that its employees requesting access are U.S. persons (as defined in 22 C.F.R. 120.15). During assignment under this MOU and while on the JPL premises and/or JPLs computing network and resources, (***NAME OF NASA EMPLOYEE***) may have access to or otherwise be provided exposure to third party proprietary and/or otherwise protected data that may not normally be available to NASA under the Prime Contract, such information and/or data shall be subject to and treated by (***NAME OF NASA EMPLOYEE***) in accordance with 18 USC 1905.

VIII. Key Personnel

The following personnel are designated the principal points of contact between the parties in the performance of this agreement:

NASA:
Roger Forsgren, Director
Systems Engineering Development Leadership Program

NASA Headquarters
MS: 6G35
300 E. Street SW
Washington, DC 20546-0001
Roger.c.forsgren@nasa.gov
Tel: (202) 358-3662

Caltech:
(name of current Associate Director)
Associate Director for Flight Projects and Mission Success

NASA Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109
Tel: (818) 354-5037
(current email)@jpl.nasa.gov

IX. Term of Agreement and Modifications

This MOU becomes effective as of the date of the last signature below. The term of this agreement is ***(ACTUAL DATE OF BEGINNING ASSIGNMENT)***, through ***(ACTUAL ENDING DATE OF ASSIGNMENT)***, or until canceled by either party. Any modification to this agreement shall be executed, in writing, and signed by an authorized representative of each party.

X. Right to Terminate

Either party may terminate this agreement at any time. One weeks notice is preferred.

XII. Anti-Deficiency Act

All activities under or pursuant to this agreement are subject to the availability of appropriated funds, and no provision shall be interpreted to require obligation or provision of funds in violation of the Anti-Deficiency Act, 31 U.S.C. 1341.

XIII. Execution

The following individuals execute this agreement on behalf of Caltech and the Government, respectively.

____________________________________ ____________________

Roger C. Forsgren **Date**
Director, Systems Engineering Development
Leadership Program

NASA Headquarters
300 E. Street SW, MS: 6G35
Washington, DC 20546-0001
Tel: (202) 358-3662

____________________________________ ____________________

Name of Current Associate Director **Date**
Associate Director for Flight Projects and
Mission Success

NASA Jet Propulsion Laboratory, California
Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109
Tel: (818) 354-5037

NASA SELDP Ethics Statement

The following SELDP Ethics Statement is required of NASA employees for SELDP assignments at JPL:

I understand that as a condition of participation in the NASA SELDP, I will consult with an ethics official in the Chief Counsels Office of my home Center prior to beginning my assignment with JPL. I furthermore understand that upon arrival, I will consult with an ethics official located in the Chief Counsels Office for the NASA-JPL Management Office. If any question regarding my compliance regarding the Federal ethics laws or other Federal or NASA ethics requirements arises during my assignment, I will contact an ethics official located in the Chief Counsels Office for the NASA-JPL NMO unless the issue relates to my official duties or other aspects or my relationship with my home Center, in which case I will contact a NASA ethics official for my home Center in coordination with an ethics official at the NASA-JPL NMO.

SELDP Participant Name Here **Date**

NASA SYSTEMS ENGINEERING BEHAVIOR STUDY

Study Leads:

Christine Williams, NASA HQ and Mary-Ellen Derro, JPL

October 2008

NASA Office of the Chief Engineer

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1.0 Executive Summary

In March 2008, the Office of the Chief Engineer (OCE) held a meeting with top NASA Systems Engineers (SEs) for the purpose of developing shared understanding and agreement regarding the practice of systems engineering across the Agency. As a critical core competency, the effective development of SEs is vital to the future of NASA's success. This development requires an understanding of the characteristics or behaviors that enable employees to be highly effective SEs.

This study was conducted to identify the characteristics or behaviors frequently observed in highly regarded SEs at NASA. Data from this study will be used to design or update systems engineering training, development, coaching and mentoring programs to develop these behaviors in SEs. This data will also help NASA Engineering Leadership to more quickly identify and support the development of high potential future SE leaders.

Centers identified "highly regarded Systems Engineers" to participate in a study to determine the behaviors that contributed to their success. The selected SEs were individuals that the centers determined as the "go to person" with regards to systems engineering. The number of interviewees varied by NASA Center. The methodology and protocol for this study mirrored a study previously conducted by the Jet Propulsion Laboratory (JPL).

In spite of the fact that the practice of systems engineering varies across centers, the behaviors of highly effective system engineers were very consistent. The consistent behaviors exhibited by NASA/JPL highly effective SEs fall into five broad top themes: leadership, attitudes and attributes, communication, problem solving and systems thinking, and technical acumen. Within each of these broad theme areas, specific descriptors of these behaviors were identified along with examples of actual behaviors associated with these theme descriptions.

The findings of this study provide a firm basis on which to build strong systems engineering competencies that will support individual development and program and project needs across NASA. The awareness and understanding of these specific behaviors will also help advance the field of systems engineering development outside NASA by providing greater focus on the human dynamics that, when combined with technical knowledge and abilities, contribute to successful engineering projects and mission success.

2.0 Introduction

2.1 Purpose

The purpose of the NASA Systems Engineering Behavior Study is to identify the characteristics or behaviors frequently observed in highly regarded SEs at NASA. The information gained from this study will be used to accelerate the development of these critical behaviors in this population in order to assure mission success and to develop the next generation of highly regarded SEs.

Data from this study will be used to design or update systems engineering training, development, coaching and mentoring programs to develop these behaviors in SEs across the agency. This study data will allow NASA to begin to introduce elements of leadership training earlier in the training process, thereby helping individuals with a propensity towards systems engineering leadership to emerge sooner.

Knowing specifically which characteristics or behaviors to target for development also provides the Agency with a more scientifically based model from which to measure the impact of training and development programs and to assess their influence on mission performance.

Additionally, this study was intended to provide NASA's Engineering Leadership with a valid and reliable template from which to assess employees' systems engineering capabilities as they relate to these behaviors, and to identify areas for development and improvement.

2.2 Background

In March 2008, the Office of the Chief Engineer held a meeting with some of NASA's top SEs for the purpose of developing shared understanding and agreement regarding the practice of systems engineering across the Agency. Historically there have been many definitions and descriptions of systems engineering used across the Agency. In fact, the actual practice of systems engineering varies across NASA. However, for the most part, SEs agree that:

> *Systems engineering is the art and science of developing an operable system that can meet requirements within imposed constraints. It is holistic and integrative and incorporates and balances the contributions of structural, electrical mechanism-design, and power engineers, plus many other disciplines, including systems safety, to produce a coherent whole that no single discipline dominates. Systems engineering is about tradeoffs and compromises, about generalists rather than specialists.*

Almost all NASA SEs also agree that systems engineering is a critical core competency in enabling the current and future success of NASA missions. This study was undertaken to understand what core behaviors are needed to build strong systems engineers.

Several actions were initiated at the March 2008 meeting to begin this development process, including updating the Academy of Program/Project and Engineering Leadership (APPEL) curriculum and establishing the Systems Engineering Leadership Development Program (SELDP) to enable top SEs to engage in hands-on, developmental "stretch" assignments that would broaden and enhance their capabilities. Foundational to these development enhancements was an understanding of the systems engineering leadership behaviors that needed to be developed in order for SEs to progress from good to great.

In order to achieve this understanding, NASA initiated a Systems Engineering Behavior Study designed to identify the behaviors that separate superior SEs at NASA from average SEs. This study looked at 38 "highly regarded" practicing systems engineers to determine the behaviors that helped make them successful.

3.0 Methodology

3.1 Behavior Study Approach

The NASA Systems Engineering Working Group (SEWG), the NASA Engineering Management Board (EMB) and senior management selected "highly regarded systems engineers" from their respective Centers to participate in a study to determine: What are the behaviors of highly regarded SEs? The methodology leverages the organizational development expertise and work previously done at JPL for the Systems Engineering Advancement (SEA) Project [5], in general, and the Systems Engineering On-The-Job Training (OJT) Program [3], [6], in particular. The selected SEs were individuals the center determined as the "go to person" with regards to systems engineering. The number of interviewees varied by Center. The names of SE participants by Center are shown in Table 12 in Appendix 1.

The Centers, along with NASA APPEL, provided team members for the study. Based on availability and the number of SEs to study, several centers provided more than one study team member. The technical background of these study team members included training and experience in one or more of the following disciplines: engineering, organizational development, psychology, and training and development. The names of study team members are shown in Appendix 2.

The SEs were interviewed, shadowed and observed by one of the study team members. The interviews were conducted in conference rooms or private offices, and were recorded. The interviews lasted from one to one-and-a-half hours. The questions were vetted and approved by the NASA Chief Engineer prior to the start of the study. Participants were asked the same questions, with follow-up questions based on initial answers. The interview questions were divided into three categories: context, relation to self and personal awareness, and the future of systems engineering. The interview questions are shown in Figure 1 below.

The shadow process included a minimum of one day of shadowing the SE performing their day-to-day activities. In addition, the study team members were invited to meetings/events the SE was either leading or participating in. The events observed included, but were not limited to, concept reviews, systems and subsystem reviews, document change reviews, project team meetings, Tiger Team meetings, and individual "quiet hours."

The interviews were transcribed, and the results were compiled and analyzed for common themes. The study team members held a validation and verification (V&V) meeting with the interviewees to gain feedback and to make changes as needed. A center report was created whenever the center had four or more SEs participating in the study. Centers with reports include GSFC, JSC, JPL, LaRC, MSFC and SSC. Data from all the centers, with the exception of KSC, has been rolled up into an Agency-wide report. Figure 2 shows these process milestones.

Context Questions

1. How would you describe the role of the SE?
2. On a scale of 1 to 10, how important is the SE in the success of a program/project?

Relation to Self and Personal Awareness

3. Create, in behavioral terms, a statement that would describe you as a SE.
4. Identify the attitudes and attributes a "highly regarded" SE possesses.
5. What leadership behaviors does a "highly regarded" SE possess?
6. As a SE, what leadership abilities do you possess?
7. On a scale from 1 to 10, how important are these abilities to mission success?
8. How are these abilities displayed?
9. What general knowledge does a "highly regarded" SE possess?
10. On a scale from 1 to 10, how important is this knowledge to mission success?
11. What values drive you as a leader?
12. How are these values reflected in your attitude?
13. Describe what goes on in your mind when you are problem solving.

Projecting Forward

14. What do you look for in determining if someone will make a good SE?
15. How will the job of an SE be different 10 years from now?
16. What will the future SE need to know and do differently?

Figure 1 SE Interview Questions

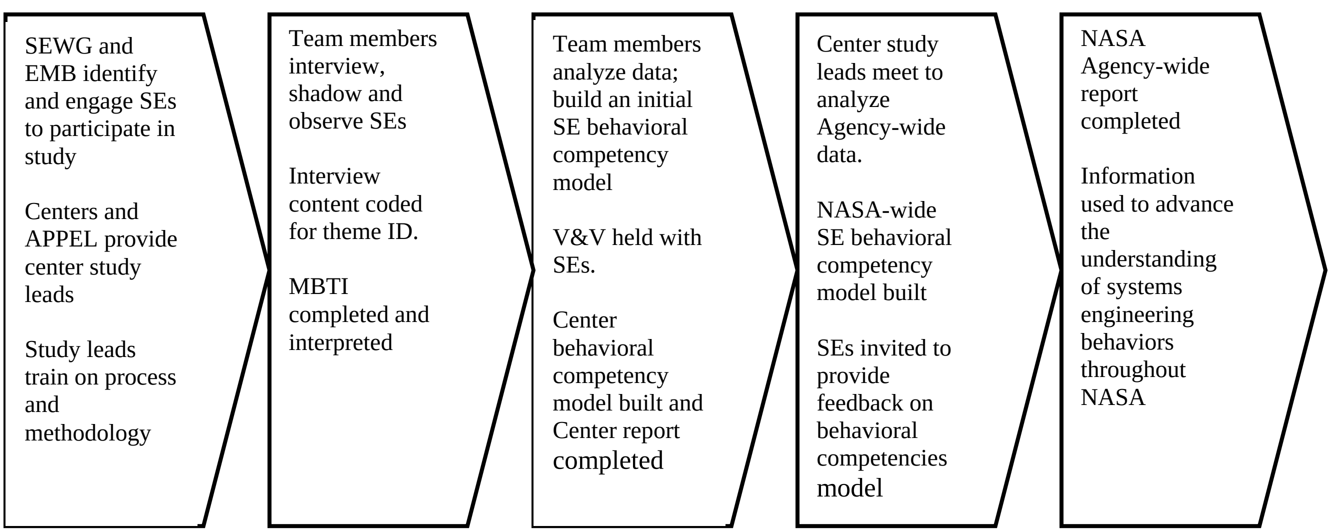


Figure 2 SE Behavior Study Process Milestones

3.2 Developing the Behavioral Competency Model Framework

Three levels of behaviors were identified as described in Table 1. The data was grouped into top behavioral competencies with middle competencies and associated behaviors. This process was done at the center level as well.

Table 1 Behavioral Competency Model Framework

Level	Description	Example
Top: Themes	Collections of competencies	Attitudes and Attributes
Middle: Competencies	Aggregations of related observable behaviors	Seeks information and uses the art of questioning
Lowest: Actual Behaviors	Observable behaviors	Asks difficult questions of discipline or subsystem experts regarding boundaries, conditions, and assumptions to ensure continuity across all systems, and to ensure the proposed solution is an integrated solution and fundamentally makes sense

4.0 Agency Findings

The behaviors exhibited by NASA's highly valued SEs fall into five broad top themes with associated competencies and their observable behaviors. The broad themes are leadership, attitudes and attributes, communication, problem solving and systems thinking, and technical acumen, as shown in Table 2. The findings are known as the NASA Systems Engineering Behavioral Competency Model. The detailed behaviors associated with the themes and competencies are shown by theme in Table 3 through Table 7 below.

Table 2 NASA SE Behavioral Competency Model – Themes and Competencies

Top Level Themes	Middle Competencies
Leadership	Appreciates/Recognizes Others
	Builds Team Cohesion
	Understands the Human Dynamics of a Team
	Creates Vision and Direction
	Ensures System Integrity
	Possesses Influencing Skills
	Sees Situations Objectively
	Coaches and Mentors
	Delegates
	Ensures Resources are Available
Attitudes & Attributes	Remains Inquisitive and Curious
	Seeks Information and Uses the Art of Questioning
	Advances Ideas
	Gains Respect Credibility, and Trust
	Possesses Self-Confidence
	Has a Comprehensive View
	Possesses a Positive Attitude and Dedication to Mission Success
	Is Aware of Personal Limitations
	Adapts to Change and Uncertainty
	Uses Intuition/ Sensing
	Is Able to Deal with Politics, Financial Issues, and Customer Needs
Communication	Listens Effectively and Translates Information
	Communicates Effectively Through Personal Interaction
	Facilitates an Environment of Open and Honest Communication
	Uses Visuals to Communicate Complex Interactions
	Communicates Through Story Telling and Analogies
	Is Comfortable with Making Decisions
Problem Solving & Systems Thinking	Identifies the Real Problem
	Assimilates, Analyzes, and Synthesizes Data
	Thinks Systemically
	Has the Ability to Find Connections and Patterns Across the System
	Sets Priorities
	Keeps the Focus on Mission Requirements
	Possesses Creativity and Problem Solving Abilities
	Validates Facts, Information and Assumptions
	Remains Open Minded and Objective
	Draws on Past Experiences
	Manages Risk
Technical Acumen	Possesses Technical Competence and Has Comprehensive Previous Experience
	Learns from Successes and Failures

Table 3 Leadership Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Appreciates/ Recognizes Others	• Articulates the relevance of the team's work and its overall contribution to the success of the program and organization. • Fairly represents individual and team contributions and gives credit where credit is due. Acknowledges work performed by others and verbally expresses appreciation.
Builds Team Cohesion	• Knows that resolving differing opinions is important to clarify the problem and foster better understanding. Works to ensure vigorous debate is allowed among people with different views, goals, and objectives to build a common framework. • Establishes healthy relationships to foster team cohesion, strong mission focus, and system perspective by asking team members to provide input and voice concerns. • Models open, non-defensive behavior with others. • Notices when others are uncomfortable and communicates acceptance with open, relaxed inquiry by making positive, encouraging comments to others throughout meetings.
Understands the Human Dynamics of a Team	• Motivates team by consistently communicating progress and understanding of the challenges and opportunities faced by the system design. • Supports team's success by consistently asking: How can I help you? What do you need to succeed? What tools do you need to do your job? • Ensures that all the disciplines interact and work together by meeting regularly and communicating progress often. • Genuinely respects people and their talents by encouraging and challenging them to do their best work. • Understands that people assimilate information differently. Builds rapport with others by adapting communication styles appropriate for the recipients. • Builds upon past experiences in successfully leading various systems engineering teams.
Creates Vision and Direction	• Keeps the team on track by holding a big picture view of what needs to be accomplished in order to reach mission requirements. • Listens to the assessments and concerns of all team members realizing each person has a point of view that is important to them, and continually reminds them of the higher goal. • Ensures each team member understands their roles and responsibilities. • Articulates to the team what constitutes system and mission success and their relationship to each other.
Ensures System Integrity	• Understands the integrity of the system is a primary role. Makes system planning decisions accordingly, reporting unacceptable project risks to senior management. • Accepts responsibility for the performance of the system. Serves as the focal point for blame and criticism when problems occur with system performance.
Possesses Influencing Skills	• Understands the political forces that affect the project and disseminates the relevant information to subsystem engineers and others, as needed.

	• Influences actions of personnel not under their direct management control by creating synergy among and with people. • Builds a base of contacts, information sources, knowledge, and expertise that may be called upon at various stages of the project. Invests the time and effort necessary to build this resource network.
Sees Situations Objectively	• Assumes responsibility for own actions without blaming others for mistakes or misrepresenting one's self. • Understands some of the best ideas can come from a mix of people. Does not assume there is only one right answer. • Remains objective so as not to be hindered by irrelevant, outside influences.
Coaches and Mentors	• Coaches and mentors team members and less experienced systems engineers to develop the breadth and depth of their competencies by giving specific positive and negative feedback for developmental purposes. • Recognizes "high potential" individuals by understanding and identifying the presence of skills and traits needed to be successful in the field. • Challenges individuals to do their best work by giving assignments that build their capabilities. • Asks questions that challenge assumptions, validate conclusions, and explore thought processes. • Promotes a team culture that places a greater priority on the performance of the system than the performance of its subsystems.
Delegates	• Delegates responsibility and authority to the lowest possible levels while retaining control of subsystem requirements and system integration functions. • Builds confidence among team members by delegating responsibility and decision-making authority to subsystem leads and then accepting the decisions they make without resistance or second-guessing.
Ensures Resources are Available	• Ensures that the team has the right tools, knowledge, and resources in order to get the job done. • Keeps abreast of current analytical tools and models by knowing where to find them, when to apply them, and how to use them. • Utilizes data archiving tools and processes to organize, simplify, and distribute information effectively. Ensures that the information team members use to make decisions and coordinate activities is reliable and trustworthy. Uses formal channels of communication to place reasonable limits on the number of people from whom information is gathered.

Table 4 Attitudes and Attributes Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Remains Inquisitive and Curious	• Is naturally inquisitive and curious, and is largely driven by that curiosity. Is fearless and has an authentic and persistent desire to understand how everything works and how it relates to everything else. Can quickly connect dots and identify weak spots. • Seeks to understand the big picture and interrelationship of the parts. Moves without boundaries from one topic to another, to discover what else needs to be known, what might be overlooked. • Actively explores the technical issues, concepts, and lexicon of subsystem disciplines that are less familiar and comfortable.
Seeks Information and Uses the Art of Questioning	• Asks difficult questions of discipline or subsystem experts regarding boundaries, conditions, and assumptions to ensure continuity across all systems and to ensure that the proposed solution is an integrated solution and fundamentally makes sense. • Asks questions, at appropriate times and in various ways, to ensure consistency of answers and to reveal if others understand what constitutes system success. Probes an area if inconsistency is revealed. • Asks questions artfully. Uses a series of questions that build upon each other to help identify the root of a problem or solutions. • Asks “Why?” “Why did we decide to do it that way?” “What were the alternative solutions, and did we do trade studies that helped us determine why this was the best solution?” • Confident in knowing what they do know and willing to state it and admit what is not known; seeks specialists to fill in missing pieces.
Advances Ideas	• Restates, reframes, and clarifies others’ questions to ensure understanding among group members by questioning and measuring an idea against system requirements. • Fosters open two-way discussions. Brainstorms with others to solicit various viewpoints. Allows and encourages people to state opinions while listening for connections and disconnects in logic. • Engages the team by explaining how the solution or approach was reached.
Gains Respect Credibility, and Trust	• Uses respectful tone, words and body language. • Follows through on commitments and serves as an advocate for the team. • Demonstrates understanding and appreciation of the challenges others face. • Earns the respect of team members by demonstrating personal integrity. Conducts business in an honest and trustworthy manner by avoiding deception and treating team members fairly. • Sees trust of self and others as a pervasive element required to achieve success. • Earns trust and respect of others by having a strong understanding of the system’s technical requirements and assigns work based on the individual’s skills and abilities. Understands that not everyone is an “A player”. • Lets team members do their job. Tells them what has to be done, but not how to do it.

Possesses Self-Confidence	• Willing to speak up, regardless of who is present to ensure the most technically sound decision is made for the good of the overall system. • Demonstrates a positive attitude and exhibits confidence. • Sits back and listens to group discussions while building models and connections and/or identifying disconnects.
Has a Comprehensive View	• Takes responsibility for the whole life-cycle, the whole system and all its parts. Understands the whole job and that it is never done. • Strikes a balance between what must happen to obtain success and what must not happen to avert failure.
Possesses a Positive Attitude and Dedication to Mission Success	• Encourages a success oriented environment by displaying passion, excitement and enthusiasm about the work and the challenges faced by the system. • Is dedicated to mission success by working until the job is successfully completed even if that means working long hours to ensure the job is done. • Creates a “can do” atmosphere by providing positive feedback and is empathetic toward team members. Encourages others with their “can do” attitude.
Is Aware of Personal Limitations	• Seeks guidance from experts. Knows what they know and what they don’t know and seeks others to fill in missing data. • Acknowledges technical limitations to others. Does this with ease.
Adapts to Change and Uncertainty	• Presses on with the project and ensures that the implications of change are addressed throughout the entire system in the face of ever-changing requirements. • May make decisions with incomplete or imperfect data. • Understands that change is inevitable and takes appropriate actions quickly. May assemble other technical experts to brainstorm various avenues and approaches to support the change. • Remains calm under pressure. Looks at things pragmatically and understands what's going on. Doesn't over-react.
Uses Intuition/ Sensing	• Uses both intuition and sensing when evaluating a problem or making a decision. Does not rely solely on data. May use of "gut feeling" if data is inconclusive. • Moves concepts and ideas easily through artificial boundaries. Uses intuition and the senses to penetrate the system and discover or synthesize solutions to a problem.
Is Able to Deal with Politics, Financial Issues, and Customer Needs	• Is politically savvy. Understands the larger forces at work. Studies the political and financial issues and impacts. • Shares and uses knowledge and expertise that shapes the political and financial environment in positive ways. • Balances tasks and deliverables against resources and designs processes that save time and money. • Possesses the ability to interface with the customer and successfully lead discussions to create an understanding of system status across various levels, both up, down and across.

Table 5 Communication Theme, Competencies, Behaviors

Middle Competencies	Actual Behaviors
Listens Effectively and Translates Information	• Sees the system from various perspectives. Listens and acts as translator between parties (subsystems, Project, vendors and other customers), ensuring each gets the necessary information from others. • Communicates project status to management and other key internal and external stakeholders. Clearly communicates requirements to providers of the subsystem elements. • Is an excellent listener. Is keenly aware of what is being said and of omissions. Listens for themes that continue to surface. Then there comes a point where the SE will begin to penetrate by asking questions. If questions are not adequately answered, the SE will begin to focus on the potential soft spot. • Listens to identify critical elements or parameters of the problem. Listens for information that leads to connections between system elements and information that disrupts connections. • Clarifies and simplifies ideas under discussion by offering and/or requesting "summation" statements.
Communicates Effectively Through Personal Interaction	• Consistently communicates progress and gains understanding from others on what challenges and successes are faced by the systems design. May meet face to face on a daily, sometimes hourly basis, to ensure everyone is in the loop understand the systems requirements. • Prefers personal interaction over e-mail. Uses face-to-face interaction as a primary communication channel to hear concerns, share information, build rapport, create buy-in and create relationships within a team. • Communicates in a clear and concise manner. • Facilitates effective communication in team meetings and throughout the project by regularly interacting with people on the team and getting them together to ensure everyone is up-to-date.
Facilitates an Environment of Open and Honest Communication	• Welcomes divergent opinions by creating an atmosphere where team members feel the freedom to openly express their opinions. Encourages and respects differing opinions in order to drive convergence on decisions. • Promotes open, honest communication by asking questions, protecting proprietary information, protecting minority opinions, and incorporating valuable ideas that are shared in the system design. Identifies and takes steps to remove communication barriers that are unique to particular individuals or groups. • Patiently listens to each of the team members/discipline experts in order to assure that everyone gets heard--that all diverse and dissenting opinions are considered. Listens to all who want to speak, does not communicate irritation and does not shut people down. • Effectively facilitate teams, meetings and disagreements. Asks clarifying, probing and penetrating questions to ensure all information is out on the table. • Demonstrates accessibility and approachability by having an open door policy.
Uses Visuals to Communicate	• Graphically pulls together ideas, issues, and observations to better understand and explain all systems and interfaces and to solve complex

Complex Interactions	problems. Uses visuals, such as Venn diagrams, models, pictures, charts, metaphors, archetypes, and other relevant representations, to communicate complex problems or to display the interconnections of sub-elements. • Keeps everyone involved by keeping accurate records of big and small picture aspects affecting the system and distributing information in advance.
Communicates Through Story Telling and Analogies	• Uses personnel experiences to build connections and provide explanations by using engineering and non-engineering stories and analogies. For example, creates analogies from historical events, everyday experiences and "life lessons" to better explain concepts and ideas to others. • Shares experiences and "lessons learned" with others to support future systems design.
Is Comfortable with Making Decisions	• Makes decisions in a confident and timely manner when appropriate – with or without complete or optimal information – allowing team members to maintain forward progress on their assigned tasks. • Carefully monitors the impact of decisions on system performance, backtracking and changing direction if necessary. When the team's forward progress is not at stake, the SE may choose to postpone decision-making and engage in more detailed analysis. • Stays on point until ideas are heard, recognizes when enough data is gathered to make a decision, and then moves on. Willing to revisit decision if new data warrants it. • Makes difficult or unpopular decisions, keeping the best interest of the system in mind, weighing the potential risks to team cohesion and interpersonal relationships against system performance.

Table 6 Problem Solving and Systems Thinking Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Identifies the Real Problem	• Identifies the critical problem to be solved by asking questions and identifying the key requirements. • Recognizes what is technically right among many good ideas by viewing a problem across system boundaries and comparing each design to the other. • Frames the problem in a logical way and identifies resources required to solve the problem efficiently. • Solves problems with the team by listening for the issue, pinpoints problem areas, makes recommendations, and then steps out. Avoids side trips and unnecessary minutiae and focuses on important issues.
Assimilates, Analyzes, and Synthesizes Data	• Assimilates and distills large quantities of data and ensures all of the data is on the table to solve a problem or make a decision. Ensures decisions made are supported with data. • Breaks data into smaller pieces or parameters, prioritizes the parameters, then synthesizes the data to reach an answer or solution. • Has the ability to rapidly recall data. • Approaches and solves problems in a systematic manner by using tools, processes, procedures in order to find solutions.
Thinks Systemically	• Looks across the entire system and facilitates trades and compromises to get a balanced design. Ensures that the integrity of the system as a whole does not suffer because of over optimizing any of the smaller pieces. • Sees multi-view representations of systems to understand how the pieces fit together and interact. Visualizes systems in 3-D. Draws a picture in his or her mind, or on paper. • Is able to look deep enough into a problem without losing focus on the big picture. Sees the big picture while at the same time demonstrating an overall awareness of the details. • Breaks the problem down into smaller manageable parts. • Understands how the system works, what it was designed to do, its functions and requirements. Is able to analyze the systems data. Traces implications of a problem in a step-by-step manner across the system.
Has the Ability to Find Connections and Patterns Across the System	• Integrates and provides a connection between the various engineering segments of the project. Is able to identify connections from separate elements of the project that others would not notice and brings these connections to the team's attention as a means to assist in solving underlying issues. • Examines and explores the implications of how technical decisions being made affect the bigger system architecture. Sees the ripple effect of changing requirements or making changes to any element of the system. • Able to see system interfaces. Identifies the impact that changes to one sub-system are having--or might have--on other sub-systems. Locates and corrects sub-system 'disconnects' or 'inconsistencies' that are having a negative impact on system performance.
Sets Priorities	• Sets technical priorities in order to maintain the balance for the problems at hand while achieving system requirements.
Keeps the Focus on Mission	• Is focused on developing a system that meets the end-item product objectives and does not lose sight of this while integrating the pieces of the

Requirements	system into the whole system. • Studies, understands, and articulates the project’s overall objectives. Knows what the system must do and be in order to accomplish its objectives. • Sets technical priorities with principal investigator and subsystem engineers to achieve system requirements.
Possesses Creativity and Problem Solving Abilities	• Enjoys and is energized by fully concentrating on a problem for long stretches, until solutions are formed and implemented. Possesses passion for problem solving. • Takes the initiative to solve the problems. • Solves problems with the team by listening to the issues, pinpointing problem areas, making technical recommendations; may help implement the solution. • Does not adhere to rigid rules or formulas for system design, but may create new ideas and approaches that are necessary to deal successfully with system constraints.
Validates Facts, Information and Assumptions	• Breaks data into smaller pieces or parameters. Prioritizes the parameters then synthesizes the data to reach an answer or solution by examining system and sub-system operations in minute detail. Recognizing that seemingly minor miscalculations can lead to significant problems in system performance. • Questions all assumptions that go into the design. • Looks for, and anticipates, problems or issues in the system in places that may not be covered with the right kind of data to make a decision. • Looks for answers that may not be readily apparent from just looking at the data alone. Does not rely solely on data.
Remains Open Minded and Objective	• Receptive to hearing diverse/varying opinions. Is willing to re-think/re-work an issue or to change direction when new information or a better idea is presented. • Evaluates decisions objectively. Maintains flexibility by avoiding 'ownership' of a particular strategy or point of view.
Draws on Past Experiences	• Draws from his or her hands-on experiences to develop the proper feel for succeeding on future projects, knowing when something looks "right" versus "not even close“ from past successes and failures. • Solves problems with a balance of innovative developments and proven heritage products. May rely on experience and existing design as guides, but sees each opportunity as a canvas to design new solutions. • Uses experience, history, intuition, and sensing in order to assess the situation and develop a solution.
Manages Risk	• Uses past experiences to anticipate potential problems that may impact system performance. • Identifies the key indicators and methods of testing for each type of problem. • Develops mitigation strategies for addressing the problems, should they arise. • Is risk savvy. Understands that risk is perpetual and needs to be managed.

Table 7 Technical Acumen Theme, Competencies and Behaviors

Middle Competencies	Actual Behaviors
Possesses Technical Competence and Has Comprehensive Previous Experience	• Shares his or her project experience, and acts as a reliable resource to the team and serves as the 'go to' person. • Demonstrates the depth of technical knowledge and expertise necessary to perform, manage, and coordinate work-related activities. • Possesses a strong, fundamental understanding of engineering principles along with a cross-disciplinary background. • Engages specialists for their technical knowledge and abilities. • Demonstrates ability to focus on details while keeping the big picture in mind. Is able to shift focus between the two with ease. • Uses an iterative process to refine the design to accomplish the system requirements
Learns from Successes and Failures	• Shares with others lessons learned. Lessons come from a strong base of engineering experiences across the full life-cycle. • Documents and studies the successes and failures of both the current and previously developed systems. Uses this information to make decisions that reduce risk and maximize the probability of success. • Is willing to learn from past failures as well as successes. Understands both are important.

5.0 Myers-Briggs Type Indicator and Temperament Results

5.1 Description of Myers-Briggs Type Indicator

The Myers-Briggs Type Indicator (MBTI®) [11] was administered to each of the highly regarded SEs in order to identify their personality or psychological type. Of the 38 SEs who participated in the behavioral study, 34 completed the MBTI®. Based on David Keirsey's work on Temperament [7], the MBTI® results can be broken down into one of four temperaments: Intuitive-Thinking (NT), Sensing-Judging (SJ), Sensing-Perceiving (SP) and Intuitive-Feeling (NF), as shown in Table 14 in Appendix 3.

5.2 MBTI® and Temperament Results

The study population has twice as many NTs (56%) as SPs (26%), followed by SJs (19%), and one participant with the NF temperament. Over half of the respondents were Introverts. Unlike the previous study at JPL, NASA centers had 9 SPs and 1 NF, while JPL had neither of these types or temperaments represented in their study. In order to maintain confidentiality, Center and participant names are not indicated. See Table 8 for the MBTI® and Temperament results.

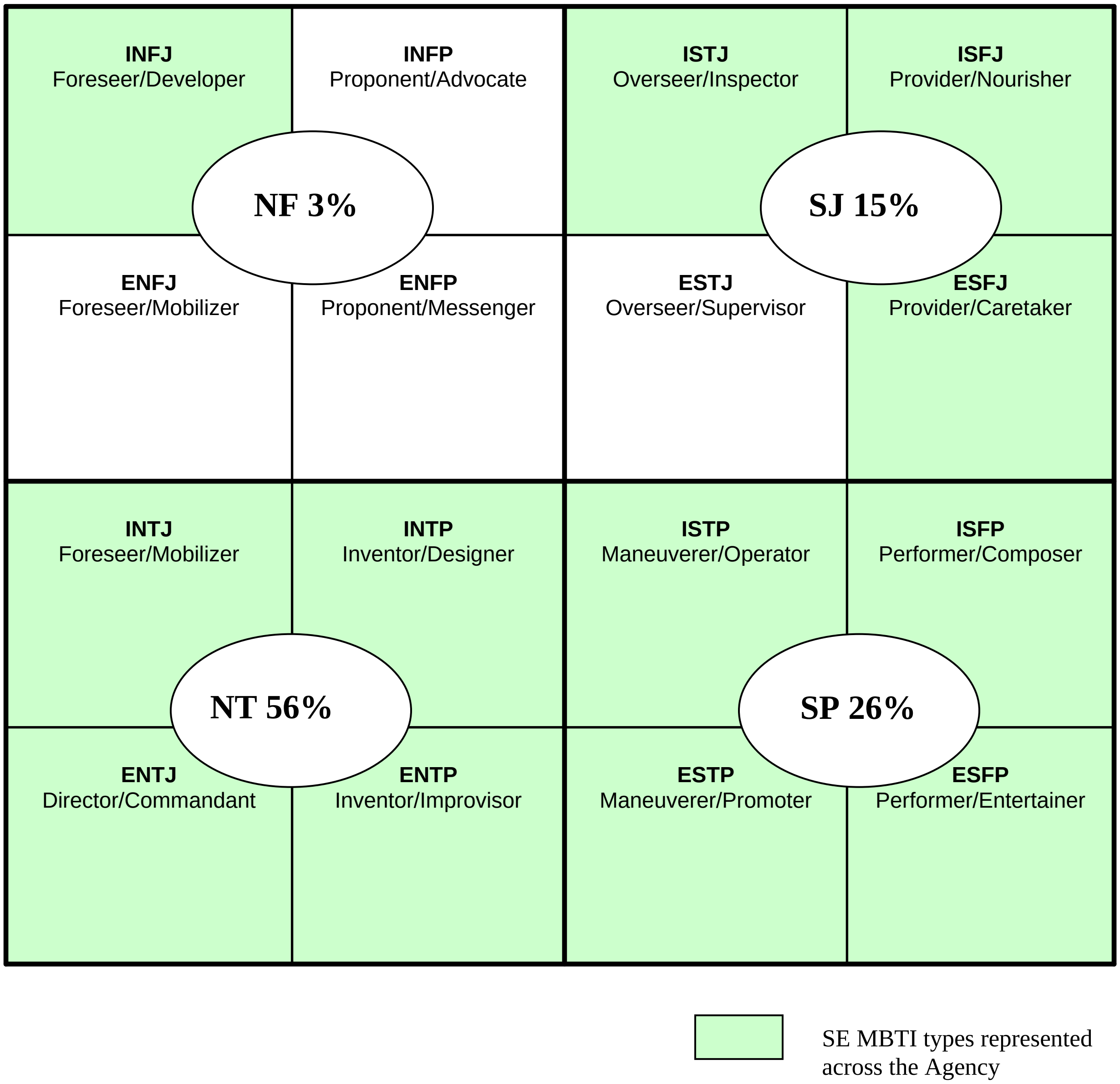
Table 8 Agency-wide Systems Engineering MBTI® Scores by Temperament

Temperaments	# by Category	% of Total	Actual Scores (e.g., INTJ where I=5, N=10, T=7, and J=8)
NT (Intuitive / Thinkers)	**19**	**56%**	
INTJ	6		**5, 10, 7, 6; 31, 5, 37, 13; 18, 6, 24, 8; 31, 29, 45, 51; 17, 8, 25, 25; **(scores not available)**
INTP	8		**30, 5, 5, 19; 11, 9, 14, 11; 12, 16, 15, 8; 7, 25, 39, 31; 16, 24, 30, 2; 4, 9, 6, 1; 4, 16, 14, 12; **(scores not available)**
ENTJ	1		**13, 39, 15, 31**
ENTP	4		**12, 8, 5, 14; 3, 15, 21, 23; 15, 4, 6, 7; 11, 29, 27, 31**
SP (Sensing / Perceiving)	**9**	**26%**	
ISTP	3		**19, 6, 8, 2; 29, 5, 27, 2; 6, 14, 18, 3**
ESTP	5		**30, 5, 24, 1; 14, 26, 5, 6; 16, 3, 1, 2; 17, 10, 20, 12; 25, 5, 8, 12**
ESFP	1		**8, 19, 3, 4**
SJ (Sensing / Judging)	**5**	**15%**	
ISTJ	3		**7, 11, 28, 29; 53, 13, 63, 39; 26, 26, 30, 30**
ISFJ	1		**21, 23, 1, 39**
ESFJ	1		**13, 3, 5, 37**
NF (Intuitive/ Feeler)	**1**	**3%**	
INFJ	1		**25, 6, 3, 28**

All but one Center showed a broad range of MBTI® types. The fact that one center had respondents with the same MBTI® type was most likely due to the small sample size, i.e., only two respondents. See Figure 3 for NASA-wide Systems Engineering MBTI® types represented in this study.

While these findings are interesting, this sample size is too small to draw any definitive conclusions. Continued work in this area will need to include additional highly regarded SEs across the Centers in comparison with those who might not be considered good candidates to be SEs.

Figure 3 MBTI® Types Occurring in SEs Studied Across the Agency



6.0 Next Steps

The OCE will share these study findings widely both inside and outside of NASA. Conference papers and presentations are being developed, and this report will be posted to the Workforce page of the Systems Engineering Community of Practice on the NASA Engineering Network (NEN) at the following URL http://nen.nasa.gov

In addition, both the APPEL and SELDP curriculums will be updated to incorporate the development of these behaviors. As part of this effort, a 360-degree Systems Engineering Behavior Instrument will be created and utilized to assess and track individual skill development. The SELDP will incorporate executive coaching based on the findings of this assessment instrument to accelerate the development of key systems engineering leadership skills during the SELDP year.

The findings of this study bring a new dimension to the understanding of effective Systems Engineering. Little has been explored or studied on the behavioral dimensions of this discipline, and therefore, the OCE is anxious to share these finding with the larger systems engineering community. Articles are being written for outside publications and these findings are already being presented at Systems Engineering Conferences.

7.0 Summary and Conclusions

There is a shared set of specific behaviors at NASA that enable individuals to excel as system engineers. These behaviors are observable and measurable. And, while these behaviors come naturally to some individuals, they are skills that potentially can be developed and learned. The SELDP is predicated on the growth mindset identified by Dweck [4] in which one sees himself or herself as a work in progress with opportunities for growth. It asserts that with effort, SEs can grow, change and learn new behaviors and skills. See Table 15 in Appendix 4.0 for a comparison of the growth vs. the fixed mindset. All the SEs who were interviewed exhibited the growth mindset.

Highly successful SEs possess a foundation of advanced technical knowledge in one or more areas. While this knowledge provides the essential footing, it is the softer, less definable skills that set these individuals apart. Creativity, curiosity, mixed with self-confidence, persistence and a knowledge of human dynamics, allows the highly regarded SEs to be successful. They have the ability to ask the questions, identify what is missing, pinpoint the soft spots in a design, then help to identify a solution to the problem. The SEs understand what must happen to obtain success and what must happen to avert failure. They are drawn to the challenge of solving complex problems by possessing an approach that is comprehensive and intentionally does not favor any particular sub-element of a system. They look across the entire system and facilitate trades and compromises to get a balance, optimized design. They exhibit excellent human relations skills, and understand how to create a vision for the team by keeping the team on track by holding a big picture view of what needs to be accomplished in order to reach mission requirements. They clearly demonstrate the growth mindset in all its many facets. These findings are consistent with the literature on highly successful and effective people [1], [2], [8], [9], [10].

The results of the initial JPL SE Behavioral Study and the Agency-wide study are similar. The results of the Agency-wide study indicate that while there are many separate Center cultures at NASA, there are also shared systems engineering behaviors that provide NASA great opportunities on which to build. Identifying and making these similarities explicit through the use of studies such as this, creates a common language and a way to build on the strengths of one of the largest brain trusts in the world. The similarities in the findings across NASA were unmistakable in proving this point.

On a discipline level, this study provides the Office of the Chief Engineer with specific, scientifically-based answers that will allow them to create learning models and strategies that will strengthen systems engineering across the Agency and build more targeted programs and policies to support mission success.

On a local level, those Centers that have produced Center-wide reports now have greater understanding of what works, and can develop ways to reproduce this success through local SE programs, mentoring and other opportunities.

On an individual level, system engineering employees can build and structure their career choices and learning options. An awareness of how they compare to the best-of-the-best will allow them and their supervisors to make more effective choices in building their development strategies.

Most NASA systems engineers stated that good systems engineering does not come from a degree in Systems Engineering, but from hands-on learning and doing, working closely with other successful SEs. They felt strongly that in ten years, the art of systems engineering and the needed SE behaviors would be the same, but that some processes and tools might be different, and that certainly the systems themselves would be larger and more complex.

While SEs need training in all three axes of the SE competency model – process knowledge, technical knowledge, and personal behaviors – the personal behaviors component is where the maximum leverage is gained. That is what separates the merely good SEs from the highly regarded and successful SEs. Unfortunately, the typical SE training program largely ignores the behavior component to the detriment of SEs. Hence, the results of this study show the need for a major paradigm shift in training SEs.

There are clearly identifiable behaviors that highly successful SEs exhibit. It is not only possible, but highly desirable, to openly communicate what those behaviors are and to encourage members of the systems engineering community to develop them. The awareness and understanding learned from this study will help advance the SE discipline not only within NASA itself, but also across the engineering community at large.

While the NASA SELDP is a start in developing the next generation of SEs, this is by no means the end, but rather only a beginning. The agency would gain value by taking this information and seriously considering inculcating these behaviors into all training for the SE Community.

8.0 Acknowledgements

Many people have contributed to the success of the study and deserve recognition, including the SEs who participated in this study and the team members who dedicated themselves to advancing the understanding of the “art of systems engineering.”

Table 9 Systems Engineers in NASA SE Behavior Study

Name	Role
Michael Ospring	Group Leader for Mechanical Systems and Analysis
Stephen Jensen	Program Chief Engineer SOFIA
James Free	Task Verification Manager Orion
Todd Tofil	Lead Systems Engineer CONNECT
Richard Wiedenmannott	Systems Engineer Integrated Environmental Test (IET) Facility (part of Orion CEV)
Peter Mike Bay	Mission Systems Engineer for Solar Dynamics Observatory
Gary Sneiderman	Instrument Systems Engineer for Astral H
David Everett	Mission Systems Engineer for Lunar Reconnaissance Orbiter
Pete Spidaliere	Mission Systems Engineer for Magnetospheric Multiscale
Joseph Bolek	Chief Flight Systems Engineer for Explores Project
Michael Menzel	Mission Systems Engineer for James Webb Space Telescope
Walt Guy	Manager of System Architecture and Integrations Office
Chris Hardcastle	Director, Constellation Program Systems Engineering & Integration
Don Noah	Manager, Space Shuttle Program Systems Engineering & Integration
John Connolly	Lead, Altair Vehicle Engineering & Integration
Kent Joosten	Assist. Manager Constellation Office of the Program Systems Engineer
Julie Kramer	Chief Engineer, Orion
Gentry Lee	Chief Engineer for Solar System Exploration, SE Fellow
Cece Guiar	Formulation Project SE for Astrophysics
Riley Duren	Chief Engineer, Kepler
Nagin Cox	Assist. Flight SE Manager on MSL and Group Supervisor
Duncan MacPherson	Systems Engineering Fellow
Glenn Reeves	Flight Software COG E for MSL Flight
Rob Manning	Chief Engineer MSL, MEP
Charles Whetsel	Project Systems Engineer, MSL
Jeff Yu	Project Architect, Advanced MIR Development Project
James Corliss	Project Engineer for Orion Landing System Advanced Development Project and ASG Experimental Facilities Development
Kurt Detweiler	Flight Test Lead Systems Engineer, Ares 1-X
John Stadler	Orion Launch Orbit Abort System Vehicle Lead Engineer
Henry Wright	Aerospace Technologist, Ares 1-X
T. David Wood	Chief Engineer, SRB
Scott Croomes	Center Deputy Chief Engineer
Garry Lyles	Associate Director for Technical Management
Dinah Williams	Sr. Systems Engineer in Spacecraft and Vehicle Systems Development
Bartt Herbert	Chief Engineer
Brad Messer	Chief of Systems Engineer and Integration Division
Nickey Raines	Deputy Chief Engineer
Steven A. Taylor	Deputy Chief of Systems Engineer and Integration Division

Table 10 NASA SE Behavior Study Team Members

Name	Affiliation
Rick Turner	Study Team Member, Marshall Space Flight Center
Jason Nelson	Study Team Member, Johnson Space Center
Jose Bolton	Study Team Member, Johnson Space Center
Katherine Thomas	Study Team Member, Academy of Program, Project and Engineering Leadership
Donna Wilson	Study Team Member, Academy of Program, Project and Engineering Leadership
Matt Kohut	Study Team Member, Academy of Program, Project and Engineering Leadership
Kathy Christian	Study Team Member, Dryden Flight Research Center
Ed Amatucci	Study Team Member, Goddard Space Flight Center
Carolyn Casey	Study Team Member, Goddard Space Flight Center
Matt Jarvis	Study Team Member, Goddard Space Flight Center
Marty Parker	Study Team Member, Kennedy Space Center
Mary Ellen Derro	Study Team Member, Jet Propulsion Laboratory

In addition, this study would not have been possible without the support from the following people:

Table 11 Sponsors, Stakeholders and Supporters of the NASA SE Behavior Study

Name	Affiliation and Role
Michael Griffin	NASA Administrator
Mike Ryschkewitsch	NASA Chief Engineer
Gregory Robinson	NASA Deputy Chief Engineer
Stephen Kapurch	NASA Systems Engineering Program Executive Officer, NASA Systems Engineering Working Group (SEWG), Chair
John Blowers	JPL Section Manager, Professional Development Section
Ross Jones	JPL Rep. to NASA Systems Engineering Working Group
Edward Hoffman	NASA Academy of Program, Project and Engineering Leadership (APPEL), Director
Wiley Larson	Stevens Institute of Technology, Director, Space Systems Engineering
Dawn Schaible	NASA Engineering and Safety Center, Manager, Systems Engineering Office
various	NASA Systems Engineering Working Group Members
Maureen Dale	RGI, Logistics Manager
Paulette Cali-Kaviana and Dennis Brundige,	JPL, Transcription Services
Lynda Jones and Mary Wiggins	GSFC, (SEVATEC), Career Coaches

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[3] Mary Ellen Derro, "Coaching Valuable Systems Engineering Behaviors,", IEEE Aerospace Conference, March 2008.

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[5] P. A. "Trisha" Jansma and Ross Jones, "Advancing the Practice Of Systems Engineering at JPL", IEEE Aerospace Conference, March 2006.

[6] P. A. "Trisha" Jansma and Mary Ellen Derro, "If You Want Good Systems Engineers, Sometimes You Have To Grow Your Own", IEEE Aerospace Conference, March 2007.

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[9] John Maxwell, *The 360 Degree Leader*, Thomas Nelson, Inc., Nashville, TN, 2005, ISBN 0-7852-6092-7

[10] John Maxwell, *Thinking for a Change: 11 Ways Highly Successful People Approach Life and Work*, Warner Books, Inc., New York, 2003, ISBN 0-446-52957-5

[11] Isabel B. Myers and Peter Myers, *Gifts Differing*: Understanding Personality Type, Consulting Psychologist Press, Inc., Palo Alto, California, 1990, ISBN-13: 9780891060741

10.0 Appendices

10.1 Appendix 1 Systems Engineering Interviewees

Table 12 Names of Systems Engineering Interviewees at each NASA Center

Center	Interviewees	Current Position
ARC	Michael Ospring	Group Leader for Mechanical Systems and Analysis
DFRC	Stephen Jensen	SOFIA Program Chief Engineer
GRC	James Free	Orion Task Verification Manager
	Todd Tofil	CONNECT Lead Systems Engineer
	Richard Wiedenmannott	
GSFC	Peter Mike Bay	Mission Systems Engineer for Solar Dynamics Observatory
	Gary Sneiderman	Instrument Systems Engineer for Astral H
	David Everett	Mission Systems Engineer for Lunar Reconnaissance Orbiter
	Pete Spidaliere	Mission Systems Engineer for Magnetospheric Multiscale
	Joseph Bolek	Chief Flight Systems Engineer for Explores Project
	Michael Menzel	Mission Systems Engineer for James Webb Space Telescope
JSC	Walt Guy	Office Manager of System Architecture and Integrations Office
	Chris Hardcastle	Director, Constellation Program Systems Engineering & Integration
	Don Noah	Manager, Space Shuttle Program Systems Engineering & Integration
	John Connolly	Lead, Altair Vehicle Engineering & Integration
	Kent Joosten	Assistant Manager Constellation Office of the Program Systems Engineer
	Julie Kramer	Chief Engineer, Orion
JPL	Gentry Lee	Chief Engineer for Solar System Exploration, Systems Engineering Fellow
	Cece Guiar	Formulation Project SE for Astrophysics
	Riley Duren	Chief Engineer, Kepler
	Nagin Cox	Assist. Flight SE Manager on MSL and Group Supervisor
	Duncan MacPherson	Systems Engineering Fellow
	Glenn Reeves	Flight Software COG E for MSL Flight
	Rob Manning	Chief Engineer MSL, MEP
	Charles Whetsel	Project Systems Engineer, MSL
	Jeff Yu	Project Architect, Advanced MIR Development Project
LaRC	James Corliss	Project Engineer for Orion Landing System Advanced Development Project and ASG Experimental Facilities Development
	Kurt Detweiler	Flight Test Lead System Engineer, Ares 1-X
	John Stadler	Orion Launch Orbit Abort System Vehicle Lead Engineer
	Henry Wright	
MSFC	T. David Wood	SRB Chief Engineer
	Scott Croomes	Center Deputy Chief Engineer
	Garry Lyles	Associate Director for Technical Management
	Dinah Williams	Senior Systems Engineer in Spacecraft and Vehicle Systems Development
SSC	Bartt Herbert	Chief Engineer
	Brad Messer	Chief of Systems Engineer and Integration Division
	Nickey Raines	Deputy Chief Engineer

	Steven A. Taylor	Deputy Chief of Systems Engineer and Integration Division

10.2 Appendix 2 Center Study Team Members

Table 13 Center Study Team Members

Center Studied	**Study Team Members**	**Home Center**
ARC	Mary Ellen Derro	JPL
DFRC	Kathy Christian	DFRC
GRC	Matt Kohut	APPEL
	Donna Wilson	APPEL
GSFC	Ed Amatucci	GSFC
	Carolyn Casey	GSFC
	Matt Jarvis	GSFC
JPL	Mary Ellen Derro	JPL
JSC	Jose Bolton	JSC
	Jason Nelson	JSC
KSC	Marty Parker	KSC
LaRC	Katherine Thomas	APPEL
	Donna Wilson	APPEL
MSFC	Rick Turner	MSFC
	Rose Opengart	MSFC
SSC	Katherine Thomas	APPEL
	Donna Wilson	APPEL
Managing Roles		
Study Director	Christine Williams	HQ/OCE
Study Director and Technical Lead	Mary Ellen Derro	JPL
Logistics Manager	Maureen Dale	HQ/RGI

10.3 Appendix 3 MBTI Description

Table 14 Myers-Briggs Type Indicator (MBTI®) Mental Processes and Orientations

Natural energy orientation	**Extraverted (E)** Face is directed towards the **OUTER** world of activities, excitements, people, and things. • Act first, think/reflect later • Feel deprived when cutoff from interaction with the outside world • Usually open to and motivated by outside world of people and things • Enjoy wide variety and change in people relationships	**Introverted (I)** Face is directed inward to the **INNER** world of thoughts, interests, ideas, and imagination. • Think/reflect first, then act • Regularly require an amount of "private time" to recharge batteries • Motivated internally, mind is sometimes so active it is "closed" to outside world • Prefer one-to-one communication and relationships
Way of perceiving or understanding and taking in information	**Sensing (S)** The **Sensing** side of our brain notices the sights, sounds, smells and all the sensory details of the **PRESENT**. It categorizes, organizes, records and stores the specifics from the here and now. It is **REALITY** based, dealing with "what is." It also provides the specific details of memory and recollections from **PAST** events. • Mentally live in the Now, attending to present opportunities • Using common sense and creating practical solutions is automatic-instinctual • Memory recall is rich in detail of facts and past events • Best improvise from past experience • Like clear and concrete information; dislike guessing when facts are "fuzzy"	**Intuitive (N)** The **Intuitive** side of our brain seeks to understand, interpret and form **OVERALL** patterns of all the information that is collected and records these patterns and relationships. It speculates on **POSSIBILITIES**, including looking into and forecasting the **FUTURE**. It is imaginative and conceptual. • Mentally live in the Future, attending to future possibilities • Using imagination and creating/inventing new possibilities is automatic-instinctual • Memory recall emphasizes patterns, contexts, and connections • Best improvise from theoretical understanding • Comfortable with ambiguous, fuzzy data and with guessing its meaning.
Way of forming judgments and making choices and decisions	**Thinking (T)** The **Thinking** side of our brain analyzes information in a **DETACHED**, objective fashion. It operates from factual principles, deduces and forms conclusions systematically. It is our logical nature. • Instinctively search for facts and logic in a decision situation. • Naturally notices tasks and work to be accomplished. • Easily able to provide an objective and critical analysis. • Accept conflict as a natural, normal part of relationships with people.	**Feeling (F)** The **Feeling** side of our brain forms conclusions in an **ATTACHED** and somewhat global manner, based on likes/dislikes, impact on others, and human and aesthetic values. It is our subjective nature. • Instinctively employ personal feelings and impact on people in decision situations • Naturally sensitive to people’s needs and reactions. • Naturally seek consensus and popular opinions. • Unsettled by conflict; have almost a toxic reaction to disharmony.
Action orientation towards the outside world	**Judging (J)** A **Judging** style approaches the outside world **WITH A PLAN** and is oriented towards organizing one's surroundings, being prepared, making decisions and reaching closure and completion. • Plan many of the details in advance before moving into action. • Focus on task-related action; complete meaningful segments before moving on. • Work best and avoid stress when keep ahead of deadlines. • Naturally use targets, dates and standard routines to manage life.	**Perceiving (P)** A **Perceiving** style takes the outside world **AS IT COMES** and is adopting and adapting, flexible, open-ended and receptive to new opportunities and changing game plans. • Comfortable moving into action without a plan; plan on-the-go. • Like to multitask, have variety, mix work and play. • Naturally tolerant of time pressure; work best close to the deadlines. • Instinctively avoid commitments which interfere with flexibility, freedom and variety

10.4 Appendix 4 Description of the Fixed vs. the Growth Mindset

Table 15 Fixed Mindset vs. Growth Mindset

	Fixed Mindset	**Growth Mindset**
Intelligence	Intelligence is static. Leads to a desire to look smart.	Intelligence can be developed. Leads to a desire to learn and grow.
Challenges	Avoids challenges	Embraces challenges
Obstacles	Gives up easily	Persists in the face of setbacks
Effort	Sees effort as fruitless or worse	Sees effort as the path to mastery
Criticism	Ignores useful negative feedback	Learns from criticism
Success of Others	Feels threatened by the success of others	Finds lessons and inspiration in the success of others
Results	May plateau early and achieve less than their full potential	Reaches ever higher levels of achievement
View	Confirms deterministic view of the world	Gives greater sense of free will

10.5 Appendix 4 Center Reports

Centers that did not interview four or more individuals did not produce a Center report. It was determined that without at least four individuals, the data set was too small to provide reliable findings. Therefore, Center reports are not available for the following three centers:

- Ames Research Center (ARC)
- Dryden Flight Research Center (DFRC)
- Glenn Research Center (GRC)

Also, as mentioned previously, findings from the Kennedy Space Center (KSC) were not available for inclusion in this report.

Note: To view the Center Reports, please go to the NASA Engineering Network (NEN) website at http://nen.nasa.gov and select the Systems Engineering Community of Practice (SE CoP). Then select the Workforce tab to view the reports.

10.5.1 Goddard Space Flight Center (GSFC) Report

10.5.2 Johnson Space Center (JSC) Report

10.5.3 Jet Propulsion Laboratory (JPL) Report

10.5.4 Langley Research Center (LRC) Report

10.5.5 Marshall Space Flight Center (MSFC) Report

10.5.6 Stennis Space Center (SSC) Report

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

February 1, 2016

Reply to Attn of: Office of the Chief Engineer

TO: Distribution

FROM: NASA Chief Engineer

SUBJECT: 2016-17 Call for Systems Engineering Leadership Development Program (SELDP) Nominations

In preparation for the 2016-17 Systems Engineering Leadership Development Program (SELDP), the Academy of Program/Project & Engineering Leadership (APPEL) is seeking nominations of high-performing engineers from NASA Centers to participate in the program.

The 2016-17 SELDP will exercise a revised format that will extend the program across 2 calendar years and provide participants added flexibility associated with hands-on development assignments. Participants will have the ability to complete their 6-9 month assignments over an 18-month period. All assignments are expected to be completed outside of the participant's home Center.

Before identifying nominees, Centers are encouraged to consider the systems engineering knowledge, skills, and abilities they will need to successfully run programs and projects 18 to 24 months from now.

To help Centers determine the best candidates for SELDP, the SELDP Selection Criteria are included in Enclosure 1. In addition, an SELDP Supervisor and Engineering Director's Application Checklist is included as Enclosure 2. This checklist is not to be included in the application package submitted to NASA Headquarters.

NASA leadership has determined that the longer the assignment, the more effective the participant becomes at leading complex systems engineering projects; therefore, 9-month assignments are given preference in the selection process. Assignments are identified by SELDP Advocates located at each Center. *NOTE: These are full-time developmental assignments and cannot be done in conjunction with other continuing home Center responsibilities.* Program details can be found at http://appel.nasa.gov/developmental-programs/seldp-overview/about-the-program.

Nominations are due April 15, 2016, and should be sent to FedStar LLC, Attn: Kevin Magee, 44081 Pipeline Plaza, Suite 305, Ashburn, VA 20147.

Nomination packages must include:

(1) NASA Form 1781 SELDP Nomination, (Enclosure 3) and NASA Form 1781B SELDP Participant Summary (Enclosure 4) for each nominee. Applications must be concise. No attachments will be accepted, and the minimum allowable font size is 11 point.

(2) A single endorsement letter covering all nominees, signed by the Engineering Director and concurred by the Center Director, must also be provided. Endorsement letters are required to be submitted in the format provided in the Engineering Director and Center Director's Nomination and Endorsement Memo Template (Enclosure 5), and must include a rank order of the Center's nominees and statements of each nominee's developmental path and the benefit to the Center/reentry strategy. An example of the requested information is also included in Enclosure 5.

*Centers are requested to identify a point of contact to coordinate the announcement and selection of nominees, and provide the name and contact information of their point of contact to Kevin Magee at kevin.magee@nasa.gov by **February 26, 2016**.*

Candidates must be available to participate in an interview on June 21, 2016, and attend Orientation in July (TBD) 2016. All information from this call letter, including the requirement to attend these two events, should be clearly communicated in the Center's call letter <u>and to all nominees</u>. See Enclosure 6 for the complete SELDP Selection Schedule.

Centers are responsible for funding their participant's salary and the following travel costs: (1) travel to/from the interview; (2) travel to/from Orientation; (3) training and associated travel that is not part of SELDP workshops; (4) additional trips home, above the allowed quarterly trip; and (5) project travel required for participants assigned to their Center. The Office of the Chief Engineer funds all other program travel and training for participants, including NASA employees assigned to JPL**.** JPL is responsible for funding all costs associated with their employee's participation in the program as noted above, with the exception of project travel required for participants assigned to their Center.

Please address questions concerning this announcement to Roger Forsgren at roger.c.forsgren@nasa.gov or 202-358-0859.

Ralph R. Roe, Jr.

6 Enclosures:
1. SELDP Selection Criteria
2. Supervisor and Engineering Director's Application Checklist
3. NASA Form 1781 SELDP Nomination
4. NASA Form 1781B SELDP Participant Summary
5. Engineering Director and Center Director's Nomination and Endorsement Memo Template
6. SELDP Selection Schedule

Distribution:
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HQ/Deputy Associate Administrator/Ms. Roe
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NASA Center Training Officers
NASA APPEL Center Contacts

Systems Engineering Leadership Development Program (SELDP)
Selection Criteria: Rating and Ranking Applications

Assessing the Nominee Against the
Art and Science of Systems Engineering

The following selection criteria will be used by the SELDP Selection Panel to rate and rank nominee applications:

Rating Factor	Maximum Points Awarded	Description
Experience (Application Question #11)	40	Has the nominee had the requisite experience in complexity and number of years to adequately prepare him/her to be successful in SELDP? Has the nominee proven to be able to effectively translate the opportunities he/she has been provided into measurable results for the Agency? Nominees will be rated on: • Relevant Past Experience: Type & Number of Years of demonstrated SE discipline knowledge and practical experience within area of expertise. • Participated in, or have an understanding and exposure to phases of project life cycle development • Discipline and/or Systems Engineering Competency • Major Accomplishments (Results Achieved) Including Awards Received
Developmental Preparation (Application Question #12)	30	How well is the candidate prepared to make maximum use of the SELDP developmental opportunity? Does he/she have the requisite training and development necessary to be successful in the SELDP? Is this the right program for this nominee at this time in his/her career? Nominees will be rated on: • Degree(s) and Certificate(s) Obtained • APPEL Training Completed • Other Professional Development • Leadership Development Including Agency-wide Courses as Applicable

Management Endorsement and Statement of Need (Center Nomination and Endorsement Memo. Additional information may also be available in Application Question #13.)	25	Does this Center consider this nominee an individual who will be considered to lead programs and/or projects within the next two to three years in a Systems Engineering role? Does the Center have a clear strategy for this individual that will effectively use the knowledge, skills and abilities gained in SELDP to support the achievement of the Center goals? Is there a good plan to enhance NASA's return-on investment? Nominees will be rated on: • Center's Overall Endorsement and Assessment of the Nominee's SE Leadership Capabilities • Alignment of Individual Development Needs with Agency/Center Program Needs • Reentry Strategy (How learning will be applied quickly?)
Discretionary	5	At the discretion of the SELDP Selection Panel member, up to 5 points can be added to the above factors, based on the information provided. This allows the panel member the latitude to recognize any exceptional strength and/or to express a clear preference for one candidate over the others despite the fact that the numerical weighting to that point may have been more or less equal.
Maximum Points Awarded	100	

SUPERVISOR AND ENGINEERING DIRECTOR'S SELDP APPLICATION CHECKLIST

No.	Item	Check Completed
1	Is the nominee a full-time permanent civil servant, grade GS-13, 14, or 15 for NASA employees, and Senior SE's at JPL?	
2	Does the nominee have a Bachelor's in engineering or AST equivalent?	
3	Have you assessed the systems engineering knowledge, skills and abilities the nominee will need to successfully run programs and projects 18 to 24 months from now; and the knowledge, skills and experience the nominee needs to obtain to support these goals?	
4	Has the nominee had NASA-wide exposure, and possesses expanded systems engineering, leadership skills and experience?	
5	Has the nominee demonstrated the leadership behaviors and aptitude listed on Attachment A, Selection Criteria?	
6	Has the nominee graduated from their Center's systems engineering program, or can they demonstrate through their experience, training and education that they have this knowledge and experience?	
7	Has the nominee taken the prerequisite APPEL SE training including Foundation of Aerospace at NASA, Project Management and Systems Engineering and Fundamentals of Systems Engineering or equivalent? If not, do they have the experience that shows they do not require this training to be successful in the program?	
8	Have you identified potential positions where the nominees' training and experience can be applied upon return, and have you talked to your nominee about what they need to focus on developing during the program to meet these needs?	
9	Have you discussed with your Center SELDP Advocate the type of assignment that will help you meet your mission and your nominee's developmental needs?	
10	Are you prepared to fully release your nominee from their current assignment(s) for 6 to 12 months?	
11	Have you reviewed the SELDP Call Letter and are you aware of the Center's funding requirements?	
12	Have you reviewed the SELDP Schedule, Attachment D, and confirmed the nominee can attend the required interviews and Orientation?	

Engineering Director and Center Director Nomination and Endorsement Template

To: NASA Chief Engineer

FROM: Center Chief Engineer/Engineering Management Board Member

SUBJECT: Systems Engineering Leadership Development Program (SELDP) Engineering Director and Center Director Nomination and Endorsement

(Center Name) is pleased to nominate the following candidates to the Systems Engineering Leadership Development Program (SELDP).

Nominee rank order and rationale:

Priority	Nominee	Nominee Development Path	Benefit to the Center/Reentry Strategy
1			
2			
3			

Signature of Center Chief Engineer/Engineering Management Board Member

Concurrence:

Name, Center Director Date

Example

To: NASA Chief Engineer

FROM: Center Chief Engineer/Engineering Management Board Member

SUBJECT: Systems Engineering Leadership Development Program (SELDP)
Engineering Director and Center Director Nomination and Endorsement

HQ is pleased to nominate the following candidates to the Systems Engineering Leadership Development Program (SELDP).

Nominee rank order and rationale:

Priority	Nominee	Nominee Development Path	Benefit to the Center/Reentry Strategy
1	Jane Smith	Jane has 20 years experience in Electrical engineering. She has been working in systems engineering for 2 years and has been assigned as lead on the XYZ program in the early phase of this project. Jane needs implementations experience. She has exhibited good leadership skills and will need more advanced communication and political savvy skills to move to the next level.	The Center is working more closely with international partners in implementing hardware and software in the XYZ project and needs to have SE's with an understanding of this phase and who can work cross culturally. With the experience Jane gains in implementation and with advanced leadership skills she will be able to support the Center in fulfilling this critical need upon her return.
2	Edgar Sanchez	Edgar has a degree in systems engineering and full life cycle experience from his experience at the Center and his position in the Air Force however all the experience is in robotics. He is now working on projects that require more collaboration with Human Space Flight Centers and University partners.	The Center will benefit great from this expanded perspective of our partners' SE processes and procedures. Edgar is our second priority because knowledge and experience currently exists to meet our immediate needs. However, the volume of work is increasing and several individuals currently working in this area are expected to retire in the next 4 years. Upon return Edgar will be well positioned to serve as a lead SE on one of our smaller projects expected to be funded in that time frame.

Signature of Center Chief Engineer/Engineering Management Board Member

Concurrence:

Name, Center Director Date

Executive Behavior Validation Study

Study Team:

Christine Williams, NASA HQ, Gabriella Belli, Virginia Tech
and Linda Morris, Virginia Tech

December 2011

NASA Office of the Chief Engineer
Academy of Program/Project & Engineering Leadership

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1.0 Executive Summary

NASA's Office of the Chief Engineer has conducted two qualitative studies to identify characteristics or behaviors frequently observed in highly regarded systems engineers and technical executives. The purpose of those studies was to develop a shared understanding and agreement across the agency regarding the practice of systems engineering, a core competency critical to NASA's success, and of the behaviors and attributes that enable highly regarded technical managers and executives to be successful.

The first study, the *NASA Systems Engineering Behavior Study*, was conducted in 2008 and included 38 civil servants in systems engineering roles at NASA field centers. The second study, *Executive Leadership at NASA: A Behavioral Framework,* conducted in 2008 and 2009, investigated behaviors and attributes of 14 NASA executives at NASA Headquarters and field centers whom agency leadership identified as highly effective in their roles, and who possessed a technical background or systems orientation that contributed to their success. Study methodology and protocol for both studies included interviewing, observing, and shadowing participants. Findings of the second study reinforced and extended those of the first study and produced 55 behaviors deemed to be essential to successful leadership. These behaviors were organized into six dimensions. For copies of the two studies, please see:

- http://www.nasa.gov/news/reports/NASA_SE_Behavior_Study.html and,
- http://www.nasa.gov/offices/oce/appel/seldp/resources/exec_leadership.html.

This is the third study in this sequence. The *Executive Behavior Validation Study* was undertaken to confirm, in a quantitative and large scale manner, the behavioral framework developed after the second small scale qualitative study. The set of 55 behaviors from that study were used to develop an online questionnaire, which was constructed to obtain two types of information from respondents: (1) the perceived importance of each behavior for successful leadership, and (2) their self-assessed skill level with respect to each behavior. Job titles in the registration list of an annual learning and knowledge-sharing event were examined in order to select individuals at an executive or managerial level. In February, 2011, 746 individuals who were thus selected were invited to participate in this study via an online questionnaire and 252 responded for a 34% response rate.

The importance ratings for the 55 behaviors were examined using correlations and a series of factor analyses in order to evaluate the underlying structure. Based on these analyses, conducted on both the entire sample and on a subset of 95 executives, the original 55 items were reduced to 26 items. These were organized into three related factors: (1) Supporting and Connecting, (2) Problem Solving, and (3) Political Savvy/Strategic Thinking. Each set of items demonstrated high internal consistency. Although the results did not corroborate the qualitatively derived six dimensions of executive behaviors, the reduced set of items in three dimensions is cleaner in structure. This reduced set of important, prioritized, executive behaviors will enable NASA to more effectively target critical development areas. A revised behavioral self-assessment reflecting these most important, core behaviors, will be easier for executives to understand. Also, tracking self-assessments on these behaviors will facilitate data collection in future studies.

2.0 Introduction

2.1 Purpose

The main purpose of this study, the *Executive Behavior Validation Study*, was twofold: (1) to assess in a quantitative manner the structure of the six dimensions constructed from 55 observed behaviors through a small scale qualitative study, and (2) to identify and prioritize the original list of 55 behaviors of highly successful technical executives in order to target developmental strategies and to refine the self-assessment used to identify developmental needs.

The end result would be a revised instrument to gather reliable data on technical executives' perceptions of what behaviors and attributes are important to their roles and what levels of proficiency they have reached in those behaviors. Such data collection efforts should assist in understanding the "art of systems engineering." The instrument should also be of assistance in workshops and training sessions to facilitate discussions of relative importance of different behaviors of highly successful executives.

A secondary purpose was to examine the resulting data and quantify the importance of the behaviors and the levels of self-described proficiency for a large group of individuals working in technical areas so as to develop a baseline of perceived importance and skill level. Additionally, comparisons based on both importance ratings and levels of proficiency could be made between executives and non-executive operating at a managerial level.

The results will extend the extensive qualitative work already done by NASA's Office of the Chief Engineer. Results from this study will provide information about what skill sets are deemed to be most important as well as which skill sets may be in need of improvement. Such information will be used to facilitate the development of these critical behaviors in a more targeted manner in order to enhance the likelihood of mission success and to develop the next generation of highly successful NASA executives.

2.2 Background

NASA's Academy of Program, Project and Engineering Leadership (APPEL) developed a 55 item questionnaire based on the observational study *Executive Leadership at NASA: A Behavioral Framework* (Williams et al., 2010). The items represent behaviors organized into six thematic categories that emerged from the observational study. For each item, respondents assessed their own skill level and rated the importance of the listed behavior for being an effective executive.

In September 2010, the Academy piloted the questionnaire with members of the Project Management Institute's Global Executive Council who attended an international conference. After making some modifications to the questionnaire based on participant feedback, APPEL conducted a large scale survey in February 2011 in order to have sufficient data to validate the six thematic categories. This report summarizes the results of that study.

3.0 Method

3.1 Participant Selection

Over 1700 national and international leaders who work in government, industry, or academic settings registered for an annual learning and knowledge-sharing event. Of these, 721 who were identified as being technical managers or executives based on their job titles received an email invitation to participate in the study and an additional 25 people who qualified were added during the two-day meeting. Although this was not a random sample, the purposeful nature of the selection was critical to constructing a potential participant pool of individuals who operated at a managerial level or higher. Of the 746 individuals invited to participate in the NASA *Executive Behavior Validation Study*, 252 responded to the online questionnaire for a 34% response rate.

3.2 Analyses

Analyses were performed using SPSS, version 17.0. Additionally, exploratory factor analyses were also performed using JMP, version 9.0, in order to confirm findings. Descriptive statistics were conducted on demographic items and to check for missing data. Factor analysis, Pearson correlations, and reliability analyses were conducted to evaluate the dimensionality of the importance ratings of 55 items. Additionally, a multivariate analysis of variance (MANOVA) was used to compare executive and non-executive responses and on the set of three scale scores. This was followed by independent sample t-tests on the scale scores individually.

When conducting exploratory factor analysis, several decisions need to be made about: (1) the method of extracting factors, (2) the number of factors to be retained, (3) the rotation method to use, and (4) the size of the sample relative to the number of items. For exploratory factor analysis, there are no absolute standards but numerous guidelines. Costello and Osborne (2005) wrote a thorough guide to best practices for exploratory factor analysis. These were used in this study.

Only 219 of the 252 respondents (87%) provided importance ratings on all 55 items. Including all the items in a factor analysis would mean a 4:1 subject to item ratio, which is on the very low side for a valid factor analysis. However, two initial analyses were performed using all 55 items. First, extracting factors with eigenvalues greater than one resulted in 15 factors explaining 67% of the variance. However, 7 factors were trivial, with only 1 or 2 items attaining loadings greater than .30. Second, to correspond with the number of dimensions from the qualitative study, six factors were extracted. These explained 48% of the variance, but item groupings were not consistent with the six original dimensions and half of the items loaded on a single factor. Neither result produced an appropriate structure. The next set of analyses, with more robust subject to item ratios, were separate factor analyses of the items within each original dimension: (1) leadership (12 items), (2) attitudes and attributes (6 items), (3) communication (13 items), (4) problem solving and systems thinking (14 items), (5) political savvy (5 items), and (6) strategic thinking (5 items).

A number of factor analyses were run on the entire sample for each of the six sets of items using three extraction methods (principle axis factoring , maximum likelihood factoring, and principal components) and both varimax and direct oblimin rotation in order to check for consistency of results. Items that cross loaded on multiple factors or were unique to a single factor were removed and analyses rerun in an attempt to find unidemensional subsets. Additional factor analyses were run on the executive group for the reduced sets of items. Ratio of items to subjects for factor analyses ranged from 31:1 to 50:1 for the entire group and from 13:1 to 19:1 for the executive group. Although the executive group was relatively small (n = 95), these analyses confirmed results from the entire group. Correlation tables for both the whole group and the executive group were examined to help determine patterns of relationships and assist with refinement and interpretation of factor analysis results. Finally, Cronbach's alpha reliability measure was used to determine the internal consistency of each resulting set of items.

4.0 Findings

4.1 Participant Profile

Over half of the 252 respondents (54%) worked for the government, 21% worked for industry, and 7% were contractors. An additional 7% worked for various non-profit, professional, or educational institutions. Over one third said that the scope of their organization was national (39%), 23% said it was global, and 21% said it was multinational (12% did not respond).

Six percent had titles of President, CEO, CFO, or CIO, 5% were Vice Presidents, and 3% were Executive Officers. An equal percent of respondents held the position of Director or Project Manager (19% each), 13% were Program Managers and 12% held other managerial positions. The largest group of respondents had responsibility at either the project level (24%) or the program level (21%). Fifteen percent were at the Corporate or Agency level, 16% at the Corporate Division or Mission Directorate level, and 10% at the Region or Center level.

About half of the respondents said they had shared decision-making authority (47%), while 29% said they had total authority and 12% said they had little decision-making authority. With respect to the number of people under their leadership, almost one-third supervised between one and 20 people (32%), 27% supervised 21 to 100 people, 12% supervised 101 to 500 people, and 7% had responsibility for over 500 people.

This was a highly educated group, with almost half having master's degrees (48%) and an additional 11% having doctorates, while 22% had a bachelor's degree. Six people (2.4%) had courses or certificates beyond the bachelor's and six had post-doctoral work. Most had worked for between one to five organizations in their career (46%), with a third having worked for between six to 10 organizations, and only 9% had worked for more than 10 organizations. Only one-quarter of the group indicated they were female, 63% indicated they were male, and 12% did not specify their gender. Their ages ranged from 31 to 79, with a mean of 52. The respondents were predominantly from the United States (78%), with only 4% from Europe. Five other regions were represented by only one to four respondents each.

Based on the entire sample, only 39% said they were NASA civil servants and only 38% said they operated at the executive level. However, of the 217 who answered both questions, 43% said they worked for NASA and 44% said they operated at the executive level. There was a statistically significant but relatively weak relationship between employment and level (χ^2 =

14.38, *p*<.001; phi correlation = .26). Of the 93 NASA employees, only 29% were at the executive level, but of the 124 non-NASA respondents, 55% were at the executive level.

4.2 Revised Item Sets based on Factor Analysis

Based on multiple sets of factor analyses, the set of 55 items in the original NASA Executive Behavior Validation instrument were reduced to 26 items in three related factors, representing three dimensions of executive behavior, which were labeled: Supporting and Connecting (10 items), Problem Solving (6 items), and Political Savvy/Strategic Thinking (10 items).

The items in these three sets were re-analyzed using both the entire sample and the executive group. A measure of sampling adequacy used to predict if data are likely to factor well is the Kaiser-Meyer-Olkin (KMO) statistic. KMO values range from 0 to 1.0 and should be .60 or higher in order to proceed with a factor analysis. Values of .80 or higher are desirable. They were above .90 for the revised item sets. Internal consistency reliabilities were also high for each set of items (.88, .82. and .90, respectively). Table 1 contains the items in the revised categories. Five of the Supporting and Connecting items came from the original leadership set, four from the communications set, and one form the original problem solving and systems thinking. All six Problem Solving items were a subset of the original problem solving and systems thinking set. The new Political Savvy/Strategic Thinking combined all the items from what was originally organized into separate sets.

Deleted Items

The remaining 29 of the original behaviors may have merit in and of themselves, but they did not provide any viable sub-scale grouping with adequate measurement properties. Additionally, while the reliabilities for various subsets of these items were not terrible, they were rather low. The KMOs for all but the set of attitudes and attribute items were in the "middling" range (.70-.79). For the executive group, the KMO for even this set fell to the middling range. The best variance explained by any subset of these items was only 41%, and the lowest was 28%. Examination of the correlation tables made evident that these 29 items do not have enough in common to justify using them in common groupings.

Consider that only one of the 21 correlations in the original set of leadership items was as high as .40, which is not a strong correlation. It represents only 16% of shared variance. The KMO results for the set of attitudes and attribute items indicate that a factor analysis is appropriate with these data. However, the pattern of correlations, communalities, and factor loadings, as well as the very low variance explained and low reliability, would warrant caution about using a scale mean based on this set of items. Five items within the original communication set seemed promising, but a single factor explained only 41% of the variance in this set, which is quite low. As originally configured, the set of problem solving and systems thinking items did not seem to represent a related, common theme. Only 4 of the 15 correlations were higher than .40. Even a factor consisting of the seemingly most cohesive subset only explained 40% of the variance, but that set of four items exhibited low internal consistency (alpha = .72).

While the relationships between item pairs within each of the above sets of items were extremely low, it might be supposed that some of these items might relate to items in other sets. To explore this possibility, the correlation matrix of this entire set of items was inspected. This showed that less than 10% of all the pair-wise correlations were greater than .40, with the strongest correlation only reaching .50. These analyses confirmed the reduction of the 55 item instrument to the 26 items that grouped together well into three related dimensions.

Table 1 Revised behavioral item sets in three dimensions

A. Supporting & Connecting 10-item scale reliability = .88
1. **Develop Employee Capabilities:** Provide resources, support and encouragement to employees for development; give work assignments that stretch them. Deliver objective, non-judgmental, constructive corrective feedback.
2. **Reduce Distractions:** Deal with issues and problems that would otherwise be a source of distraction for staff.
3. **Aware of Self and Values:** Know personal strengths, limitations and motivations and when to consult others. Be aware of blind spots or biases and articulate values.
4. **Develop Self:** Maintain basic working knowledge of technical discipline, conducting bench marking with pertinent organizations. Develop a learning plan for position/new roles.
5. **Let Go of Current Role to Prepare for New One:** Willing to relinquish familiar job functions and develop skills and knowledge necessary to grow and advance to the next level of leadership.
6. **Strive for Clarity:** Use clear language; compare and contrast ideas; summarize decisions and agreements at meetings.
7. **Ensure Understanding:** Solicit feedback to check for understanding; align verbal and nonverbal messages.
8. **Assess Context:** Know when and how often to communicate. Sense others' needs and strike the right balance in communicating what is needed, but not more.
9. **Encourage Participation:** Ensure all opinions are solicited. Use facilitation, coaching, or dialogue skills. Ask open-ended questions. Sense when opinions are being suppressed.
10. **Remain Open-Minded and Objective**: Receptive to diverse and dissenting opinions; willing to re-think/re-work an issue or to change direction.
B. Problem Solving 6 item scale reliability = .82
11. **Find Connections and Patterns:** Observe system interfaces and ripple effects of changing requirements/ elements; locate/correct sub-system 'disconnects' or 'inconsistencies.'
12. **Assimilate, Analyze, and Synthesize Data and Information:** Assimilate and distill large quantities of data from across organization, break data down, establish parameters, set priorities, and synthesize.
13. **Validate Facts, Information and Assumptions:** Question assumptions, anticipate problems, and recognize data have limitation
14. **Consider All Options before Deciding:** Actively seek and weigh different perspectives. Look at all aspects of the organizational system.
15. **Identify, Assess, and Manage Risk:** Manage risk as an ongoing process: ask questions, identify worst-case scenarios, test methods, and develop mitigation strategies.
16. **Acknowledge and Manage Uncertainty:** Analyze failures and openly and honestly discuss successes, failures, and lessons learned.

Table 1 (continued)
C. Political Savvy & Strategic Thinking 10 item scale reliability = .90
17. **Know How the Political System Works:** Know who makes decisions and what they need to make hem. Have a keen sense of timing when opportunities arise.
18. **Have Political Staying Power:** Able to maintain momentum over many years. Assess political and budget realities in context.
19. **Represent/Promote Organization's Programs across Political Spectrum:** Understand and effectively communicate with government leadership on how programs meet organizational and national needs. Explain consequences and implications of organization's decisions.
20. **Manage Multiple Demands/ Opportunities:** Balance needs and political interests of internal and external stakeholders. Be aware of what is important to management and other key players and keep them informed on pertinent matters.
21. **Provide Historical Perspective:** Help others see and understand historical progression of strategies and decisions. Use/promote lessons learned to avoid repeating mistakes.
22. **Maintain an Organization-Wide View:** Make decisions by keeping the big picture and working the larger organizational trade space.
23. **Manage Near-Term and Long-Term Goals:** Proactively anticipate and position the organization years in advance; set a path and stick to it for extended time period
24. **Understand Broad Implications of Activities at Multiple Levels:** Understand where the organization's mission connects to other organizations; seek connections and partnership; share information and communicate on shared goals and projects.
25. **Monitor the Environment:** Monitor the external environment to understand issues, priorities or actions that may impact the organization. Work with others with mutual interests to leverage overall program investments.
26. **Use Networks:** Build and use informal networks to validate and gain additional information, looking to many different sources to be sure issues are covered and connecting organizations and individuals to accomplish goals.

4.3 Sub-scale Mean Responses and Correlations

Mean responses for both perceived importance and self-assessed skill level are presented in Table 2 for the entire group of 252 respondents, as well as for two self-identified groups: 95 executives and 122 non-executives (35 respondents did not self-identify with either category).

Based on a response scale from 1 = very low to 5 = very high importance for each item, the three dimensions of executive behavior were all seen as fairly important to an almost equal degree, averaging 4.0, 4.1, and 4.2. Also based on a response scale from 1 = very low to 5 = very high, the self-assessed skill level means were all slightly lower than 4 points, but still reasonably high. Although differences were relatively minor, Political Savvy/Strategic Thinking had the highest mean for importance (4.2), while Problem Solving had the highest mean for skill level (3.9). Mean scores for the 29 items that were eliminated via factor analysis were equivalent to the highest mean in both subscale sets.

Table 2. Subscale means for perceived importance and self-assessed skill level of three dimensions of executive behaviors by executives and non-executives

Subscales	N	Mean (sd) Total group	Executives	Non-executives	Mean difference	*t*	*p*
Importance Means							
Supporting and Connecting	251	4.0 (.5)	4.0 (.5)	3.9 (.5)	.11	1.50	.14
Problem Solving	225	4.1 (.5)	4.1 (.6)	4.0 (.5)	.09	1.21	.23
Political Savvy/Strategic Thinking	224	4.2 (.5)	4.2 (.6)	4.1 (.5)	.07	0.94	.35
Original items not in scales	251	4.2 (.4)					
Skill Level Means							
Supporting and Connecting	252	3.7 (.5)	3.8 (.5)	3.7 (.4)	.13	1.98	.05*
Problem Solving	225	3.9 (.5)	4.0 (.5)	3.8 (.5)	.19	2.68	.01**
Political Savvy/Strategic Thinking	224	3.7 (.6)	3.8 (.6)	3.6 (.6)	.24	2.85	.01**
Original items not in scales	252	3.9 (.4)					

A multivariate analysis of variance (MANOVA) indicated that there was no statistically significant difference between the two groups on the set of three importance subscale scores (Wilks' Lambda = .989 & $F(3,212) = 0.80$, $p = .50$). The very small higher mean scores for the executive group were not statistically different from the means in the non-executive group. There was a statistically significant difference between the two groups on the set of three skill level subscale scores (Wilks' Lambda = .958 & $F(3,212) = 3.09$, $p = .03$). As would be expected, subscale means for skill level were all somewhat higher for executives than for the non-executive group. Follow-up *t*-tests provided similar results for the individual subscales, indicating no differences for each of the three importance means, but statistically significant differences for each of the three skill level means.

As shown in Table 3, the three sub-scale scores were all moderately related to each other, more so for the importance subscale means than for the skill level means.

Table 3 Correlations for sub-scale mean scores

	Correlations on Importance Means			Correlations on Skill Level Means		
	1	**2**	**3**	**1**	**2**	**3**
1. Supporting & connecting	1			1		
2. Problem solving	.65	1		.52	1	
3. Political savvy/strategic thinking	.68	.67	1	.57	.66	1

Correlations between means for importance and skill level for the same sub-scales were moderately low. The correlation was .48 for the two sets of mean scores for supporting and connecting, .53 for problem solving, and .41 for political savvy/strategic thinking.

4.4 Item Responses

Although the scale scores indicate that these three dimensions of executive behavior are perceived to be very important, each dimension consists of a set of related items. To fully explore the elements in these dimensions, the following tables provide the percent of high and very high responses for each item for both perceived importance and skill level. While a larger proportion of executives than non-executive tended to indicate a behavior as highly important, some behaviors were viewed as important by more non-executives. As would be expected, more executives than non-executives perceived themselves as highly skilled at all but one of the behaviors (ensure understanding). Response percentages for the 29 items omitted from the final scales are provided in Appendix 8.1.

Perceived Importance of Behaviors

Table 4 contains the percentage of responses in the top two importance ratings (high and very high) for the reduced item set, with items ranked within each category. Item numbers refer to the original numbers as listed on the questionnaire with 55 items. Across all respondents, the four Supporting & Connecting items that were seen as most important by over 75% of the respondents were: (1) strive for clarity (82%), (2) develop employee capabilities (79%), (3) remain open-minded and objective (78%), and (4) encourage participation (75%). These same four behaviors were rated as most important by both the executives and the non-executives, except in different order.

The two Problem Solving items that were rated most important by 75% or more of the respondents were: (1) identify, assess, and manage risk (79%) and (2) acknowledge and manage uncertainty (75%). These were also the top two importance items for both groups, with most of the executives finding these categories of high or very high importance (91.6% and 86.3%, respectively), but a slightly lower percentage of non-executives doing so (86.9% and 81.1%, respectively).

Over 75% of the respondents found three Political Savvy/Strategic Thinking items to be of high or very high importance: (1) know how the political system works (79%), (2) manage multiple demands/opportunities (79%), and (3) manage near-term and long-term goals (76%). These were also the top three importance items for both groups.

Self-assessed Skill Levels

Table 5 contains the percentage of responses in the top two skill level ratings (high and very high) for the reduced item set, with items ranked within each category. Item numbers refer to the original numbers as listed on the questionnaire with 55 items. Overall, the largest number of respondents said they were highly skilled at striving for clarity (72%) and the smallest number said they were highly skilled at representing/promoting the organizations programs across the political spectrum (40%).

Over three-quarters of the executives rated themselves as highly skilled at five behaviors (3 supporting and connecting and one each from problem solving and political savvy/strategic thinking). In contrast, the highest proportion of non-executives who rated themselves as highly skilled was 71% and this was for only two behaviors (striving for clarity and awareness of self and values).

Comparison of Executive and Non-Executive Responses

Although there was no statistically significant difference between the 95 executives and the 122 non-executives on the three subscale scores, there were some slight differences in the perceived importance rankings of individual items. While over three-quarters of the behaviors were rated as having high or very high importance by a greater percentage of executives than non-executives, some of the behaviors were seen as more important by the non-executive group. However, these differences were all less than three percentage points. The three behaviors rated as important by over 10% more of the executives than the non-executives were: (1) let go of current role to prepare for new ones, (2) assimilate, analyze, and synthesize data and information, and (3) monitor the environment. A larger percentage of executives rated their skill level as high or very high on all but one behavior. But that difference was minor. Slightly more than half of both groups assessed their skill to "ensure understanding" as high or very high (54% of the executives and 52% of the non-executives). See Table 6 for a complete comparison of the two groups.

Within each subset of behaviors, the two groups were in agreement as to the top two important behaviors. In the Supporting and Connecting set, these were: (1) strive for clarity and (2) remain open-minded. In the Problem Solving set, they were: (1) identify, assess, and manage risk and (2) acknowledge and manage uncertainty. In the Political Savvy/Strategic Thinking, they were: (1) know how the political system works, and (2) manage multiple demands/opportunities.

Table 4 Behaviors ranked by IMPORTANCE within categories (N = 252)

	Total % High and Very High	
Supporting & Connecting	**Importance**	**Skill Level**
21a. Strive for Clarity	81.7	72.2
8. Develop Employee Capabilities	79.0	63.1
42. Remain Open-Minded and Objective	77.8	63.1
27. Encourage Participation	75.4	61.1
10. Aware of Self and Values	72.6	69.4
21b. Ensure Understanding	72.6	51.6
22. Assess Context	65.9	49.2
12. Let Go of Current Role to Prepare for New One	64.3	57.9
11. Develop Self	63.1	49.6
9. Reduce Distractions	60.7	52.8
Problem Solving	**Importance**	**Skill Level**
40. Identify, Assess, and Manage Risk	79.0	58.7
41. Acknowledge and Manage Uncertainty	74.6	67.1
38. Validate Facts, Information and Assumptions	71.8	61.1
39. Consider All Options before Deciding	70.6	60.3
37. Assimilate, Analyze, and Synthesize Data and Information	64.3	57.9
36. Find Connections and Patterns	63.5	58.7
Political Savvy/Strategic Thinking	**Importance**	**Skill Level**
45. Know How the Political System Works	79.4	49.2
48. Manage Multiple Demands/ Opportunities	79.0	58.7
51. Manage Near-Term and Long-Term Goals	76.2	58.7
47. Represent/Promote Organization's Programs across Political Spectrum	72.6	39.7
50. Maintain an Organization-Wide View	72.2	61.9
52. Understand Broad Implications of Activities at Multiple Levels	71.4	52.8
46. Have Political Staying Power	70.2	44.0
54. Use Networks	70.2	42.9
53. Monitor the Environment	67.1	44.0
49. Provide Historical Perspective	63.1	53.2

Item numbers refer to the original numbers as listed on the questionnaire with 55 items.

Table 5 Behaviors ranked by SKILL LEVEL within categories (N = 252)

	Total % High and Very High	
Supporting & Connecting	**Importance**	**Skill Level**
21a. Strive for Clarity	81.7	72.2
10. Aware of Self and Values	72.6	69.4
8. Develop Employee Capabilities	79.0	63.1
42. Remain Open-Minded and Objective	77.8	63.1
27. Encourage Participation	75.4	61.1
12. Let Go of Current Role to Prepare for New One	64.3	57.9
9. Reduce Distractions	60.7	52.8
21b. Ensure Understanding	72.6	51.6
11. Develop Self	63.1	49.6
22. Assess Context	65.9	49.2
Problem Solving	**Importance**	**Skill Level**
41. Acknowledge and Manage Uncertainty	74.6	67.1
38. Validate Facts, Information and Assumptions	71.8	61.1
39. Consider All Options before Deciding	70.6	60.3
40. Identify, Assess, and Manage Risk	79.0	58.7
36. Find Connections and Patterns	63.5	58.7
37. Assimilate, Analyze, and Synthesize Data and Information	64.3	57.9
Political Savvy/Strategic Thinking	**Importance**	**Skill Level**
50. Maintain an Organization-Wide View	72.2	61.9
48. Manage Multiple Demands/ Opportunities	79.0	58.7
51. Manage Near-Term and Long-Term Goals	76.2	58.7
49. Provide Historical Perspective	63.1	53.2
52. Understand Broad Implications of Activities at Multiple Levels	71.4	52.8
45. Know How the Political System Works	79.4	49.2
46. Have Political Staying Power	70.2	44.0
53. Monitor the Environment	67.1	44.0
54. Use Networks	70.2	42.9
47. Represent/Promote Organization’s Programs across Political Spectrum	72.6	39.7

Item numbers refer to the original numbers as listed on the questionnaire with 55 items.

Table 6 Comparison of executive & non-executive response percentages

Behaviors ranked by IMPORTANCE for EXECUTIVES *within categories*	Total % High and Very High			
	EXECUTIVES (N = 95)		NON-EXECUTIVES (N = 122)	
Supporting & Connecting	**Importance**	**Skill Level**	**Importance**	**Skill Level**
21a. Strive for Clarity	**88.4**	85.3	84.4	70.5
42. Remain Open-Minded and Objective	**87.4**	76.8	86.1	64.8
27. Encourage Participation	**85.3**	71.6	77.9	60.7
8. Develop Employee Capabilities	**81.1**	76.8	78.7	60.7
21b. Ensure Understanding	74.7	53.7	**77.0**	55.7
10. Aware of Self and Values	72.6	74.7	**76.2**	70.5
12. Let Go of Current Role to Prepare for New One	**69.5**	58.9	59.0	56.6
22. Assess Context	68.4	55.8	**70.5**	48.4
11. Develop Self	**66.3**	53.7	60.7	50.8
9. Reduce Distractions	**63.2**	54.7	59.8	50.8
Problem Solving	**Importance**	**Skill Level**	**Importance**	**Skill Level**
40. Identify, Assess, and Manage Risk	**91.6**	72.6	86.9	60.7
41. Acknowledge and Manage Uncertainty	**86.3**	85.3	81.1	67.2
38. Validate Facts, Information and Assumptions	**85.3**	74.7	77.9	63.9
37. Assimilate, Analyze, and Synthesize Data and Information	**78.9**	69.5	66.4	63.1
39. Consider All Options before Deciding	77.9	70.5	**80.3**	64.8
36. Find Connections and Patterns	**72.6**	73.7	70.5	59.0
Political Savvy/Strategic Thinking	**Importance**	**Skill Level**	**Importance**	**Skill Level**
48. Manage Multiple Demands/ Opportunities	88.4	68.4	**89.3**	63.9
45. Know How the Political System Works	88.4	64.2	**90.2**	47.5
51. Manage Near-Term and Long-Term Goals	**87.4**	74.7	85.2	59.8
52. Understand Broad Implications of Activities at Multiple Levels	**85.3**	67.4	78.7	54.9
46. Have Political Staying Power	**84.2**	55.8	76.2	43.4
47. Represent/Promote Organization's Programs across Political Spectrum	**83.2**	55.8	81.1	36.1
53. Monitor the Environment	**82.1**	58.9	72.1	43.4
50. Maintain an Organization-Wide View	80.0	80.0	**82.0**	63.1
54. Use Networks	80.0	52.6	79.5	43.4
49. Provide Historical Perspective	**71.6**	68.4	70.5	53.3

Item numbers refer to the original numbers as listed on the questionnaire with 55 items.
Bold values indicate the larger percentage between two importance and two skill level rankings.

4.5 Open-ended Comments

An almost equal number of executives (38) and non-executives (33) responded to an open-ended question asking for comments about what it takes to be an effective executive. However, a much higher proportion of executives (40%) than of non-executives (27%) responded, with three comments made by unidentified respondents. A content analysis of the comments was used to organize them into themes. Over half the comments were about executive practices. These were organized into the following categories: lead/manage people; exemplify integrity, honesty, courage; build and act on vision/big picture; listen and communicate; care and understand others; make decisions and delegate; focus on long-range goals; be flexible and keep learning; establish respect. Twelve comments were about executive roles and eight were advice for executives. Additionally, four comments were specific to executives in NASA and five about the survey itself. (See Appendix 8.2 for a complete listing of all the comments.)

Nine comments about leading or managing people dealt with the importance of people skills. The five non-executives were more likely to directly mention "*people skills*" while the four executives broke "people skills" down into more finite behaviors by indicating that one should "*maintain a healthy relationship*" with difficult customers, identify and keep "*high quality people*," and "*inspire teams to focus on the mission*."

Seven executives provided direct advice for other executives, such as, "*delegate*," "*establish clear lines of authority and accountability*," be willing to take risks, make decisions, and always communicate and lead by example. A non-executive advised to "*keep it simple*."

5.0 Summary and Conclusions

The main purposes of the *Executive Behavior Validation Study* have been accomplished. Although the structure of the original six dimensions found through qualitative observation and interviewing were not substantiated as originally conceived, a subset of the behaviors did realign into three useful dimensions. The new subsets with the reduced item set hold together well both statistically and conceptually. This allowed for a refinement of the questionnaire, which should be useful in many future ventures.

The secondary purpose of quantifying the perceived importance of these behaviors and the levels of self-assessed proficiency for a large group of individuals in executive and managerial positions had extremely positive results. Importance ratings for all three subscales were 4.0 or higher on a 5-point scale. Nine of the 26 behaviors were deemed as having high or very high importance by over three-quarters of the 252 respondents. The rest of the behaviors were deemed highly important by over 60% of all respondents. Over 80% of the executive group rated 16 of the behaviors as having high or very high importance (4 of 10 supporting and communicating behaviors, 3 of 6 problem solving behaviors, and 9 of 10 political savvy/strategic thinking behaviors).

Results with respect to self-assessed skill levels were also gratifying. From over half to 85% of the executives rated themselves as having a high or very high skill level in each behavior. This indicates that while there is certainly room for improvement, these core behaviors are being practiced and practiced reasonably well. As would be expected, the group of non-executives rated their skill levels lower than did the executives. NASA now has a baseline for what skills may need improvement.

6.0 Next Steps

Findings from this study provide a refinement of the list of critical behaviors for successful technical executives determined from prior work. These findings will allow NASA to refine training and development and experiential opportunities for individuals moving into executive positions. The revised instrument can be used to assist in formal training sessions for such individuals as well as allow executives to assess their own skills in three main areas.

The revised instrument may also be an invaluable tool in undertaking more elaborate research to gain a better understanding of how executives in technical areas can develop and be successful. When a paper by Morris and Williams (2011) summarizing the results of the second study in this series was presented at the 12th International Conference on Human Resource Development, there was an expressed interest from German and Brazilian members of the project management community in creating joint research projects in order to gain an international perspective on importance and skill levels of executive behaviors.

7.0 Acknowledgements

Many people have contributed to the success of the study and deserve recognition. In particular we want to express our gratitude to the 252 executives, directors, and managers who gave of their valuable time to respond to a very lengthy questionnaire. It is because of this participation that we are able to advance the understanding of the “art of systems engineering.”

In addition, this study would not have been possible without the support from the following people:

Michael Ryschkewitsch	NASA Chief Engineer
Edward Hoffman	Director, NASA Academy of Program/Project & Engineering Leadership (APPEL)

8.0 Appendices

Appendix 8.1 Response percentages for 29 items not in final scales

Behaviors ranked by **IMPORTANCE**	**Total % High and Very High**	
(N = 252)	**Importance**	**Skill Level**
1. Create Organizational Structure	93.3	79.0
5. Act Decisively	93.3	73.4
3. Manage at the Appropriate Level	90.5	73.8
2. Gauge Resource Needs to Achieve Mission Objectives	90.1	74.2
17. Remain Calm under Pressure	90.1	69.0
4. Accept Change and Be Resilient	89.7	77.8
6. Inspire and Motivate Team Members to Perform at Peak Performance	89.7	67.7
7. Build Trust and Respect Confidentiality	89.3	87.3
19. Communicate throughout the Organization	88.1	66.7
24. Practice Effective Speaking and Listening Skills	88.1	68.3
15. Organized	87.3	73.8
16. Display Self-Confidence and Courage	86.5	76.6
18. Aware of How Personal Presence and Behavior Affects Others	84.5	67.5
34. Identify and Define Core Issues/ Problems	80.2	72.6
28. Seek Expert Opinion	78.6	67.5
26. Link People, Organizations, and Ideas	76.6	63.9
30. Build Relationships through Interaction	75.8	59.9
13. Inquisitive and Curious	74.2	76.2
33. Think Systemically	74.2	72.2
35. Actively Probe for Information and Understanding	73.8	64.7
20. Tailor Messages	72.6	66.7
31. Demonstrate Accessibility	72.6	73.4
29. Build Consensus	70.2	61.9
43. Use Creativity in Solving Problems	69.4	59.5
44. Draw on Past Experience	67.9	68.7
14. Patient	67.5	57.1
32. Use Systems Perspective	65.1	55.6
23. Create Positive Climate	58.3	71.0
25. Communicate through Story Telling and Analogies	41.7	46.0

Appendix 8.2 Written comments by executives and non-executives

*	Executive Practices
	Lead/ Manage People
E	A certain amount of stubbornness is important as well as knowing when to be stubborn and unyielding in your position. Suffering fools gladly is also important, we all have customers that can be irrational or hard to get along with, it is important to know how to deal with these people and maintain a healthy relationship.
E	Identifying and getting high quality people and then keeping them
E	Always complement your own strengths and weaknesses with others who can help the organization be more complete. Not a technical expert? Have them on your staff.
E	Inspire a team to make schedule at high quality, instead of acting like analysts who get to decide whether to do so. Also, inspire teams to focus on the mission and not sub optimize it for institutional agendas. This is a significant issue for us currently.
NE	The higher you rise in management, the more important people skills become. You can delegate implementation/executing tasks to someone else. But you cannot delegate effective people skills to anyone else. You must be able to do that yourself. I would rate having excellent people skills above excellent technical skills because all work is accomplished through people.
NE	It is important to establish trusting partnerships with customer and consumer organizations. Also import to know when to empower employees and when to mentor or lead. Micromanaging is rarely warranted in my experience, and never appreciated. Providing a structure for people to flourish, create an environment that ensures they feel appreciated and valued, and helping them avoid career stagnation is critical to keeping a team productive.
NE	The most important thing to be an effective executive is to have good people leadership skills. It is better to be respected than feared; better to be a good listener than wanting to be heard all the time; better to be humble and come out as a person who has all the right answers....
NE	People skills
NE	You need to be able to influence people at any authority level.
	Exemplify Integrity/Honesty/Courage
E	If you say a contractor must utilize EVMS to manage then understand it and use it yourself. Don't pay lip service to it.
E	Integrity, hard work, drive, dedication
E	Key is Integrity, consistency and willingness to recognize that as an executive we do not have all the answers
E	Act with integrity - treat others with respect. Articulate a vision, establish goals, and communicate the desired future state. Act decisively. Encourage open exchange of ideas.
NE	Honesty and courage
NE	Courage to hold self and other accountable, and integrity--which constitutes dependability and trustworthiness.
NE	A strong desire to do the right thing.
NE	Honesty, integrity, patience, listening, empathy, self-understanding

** E = comment made by an executive; NE = comment made by a non-executive.*

Appendix 8.2 (continued)

	Build and Act on Vision/ Big Picture
E	Vision, bias for action, drive, openness to contrary evidence.
E	An effective executive has to be able to 'slice and dice' every situation that impacts his/her organization, being able to see the big picture while understanding the details of the moving parts, and fully appreciate the complexities of creating/maintaining a successful organization.
E	Big picture perspective, with enough solid technical knowledge of the topics to ensure credibility when managing.
NE	Most important behavior is to have a vision of direction and expectations and make sure that it is shared.
NE	Must be 100% committed to the ultimate desired outcome (however that is defined), demonstrate this commitment in all actions every day and understand that this outcome is only accomplished by engaging all members of your "team" toward a shared vision of that outcome and each of them at their full potential.
	Vision, teamwork, leadership and good organizational skills
	Have to maintain a corporate view and know how your task fits in.
	Listen: Communicate
E	Be able to "actively listen", be intuitive, trust your instincts, and willing to change and adapt - change is the only constant.
E	In addition to the above - Very good listening and comprehension skills
E	Collaboration, communication and effective compromise are important when working in a large organization with diverse product lines
E	Active listening and willingness to be open and share insight and vision
E	I think the most important skills are listening to be open to what people are trying to tell you, continually learning how to better use the information they are sharing, and training yourself to do the management "processing" (synthesizing, analyzing, organizing, communicating) in an efficient, timely, and collegial manner.
	Care; Understand Others
E	You have to continually put the needs of the team and the stakeholders ahead of your own personal ambitions and needs. It's more about the team than it is about you.
E	An ability to fully understand other's perspectives–what motivates, what's important, what's not important–without projecting ones own experiences and feelings.
E	Be there for your employees and your management and deliver product
NE	They have to care.

Appendix 8.2 (continued)

	Make Decisions and Delegate
E	You will need to tradeoff all of the data and make a decision. It will seldom be unanimous so you cannot wait or it will never get done. Once made you need to stick with it and push to get everyone on board. Believe and they will follow. Pick people you can trust and then trust them. Push. If it turns out to be wrong admit it, adjust it and proceed. Move, don't stand and debate.
NE	An effective executive needs to be able to delegate responsibility and authority for tasks. This requires the ability to mentor, judge other's capabilities accurately, delegate, trust and make hard decisions (such as replacing someone if they are unable to be mentored to get the work done).
NE	Trust yourself, listen to informed opinions and do not be afraid to make a decision
NE	Self-awareness, decisiveness, effective use of team members, delegation, ability to lead and motivate team members, manage near-term and long-term goals, effective communication at all levels.
	Focus on Long-Range Goals
E	Must always be able to balance the political environment with the long-range goals of the organization and navigate the organization through the political environment toward the long-range goal. Analogy of a sailboat tacking in the wind but always moving toward the objective.
E	Always make decisions based on the long term impacts and recognize you are in an executive position for the benefit of the program/people/company not your own.
NE	Be visible, communicate with all levels of employees, and keep focus on long-term strategy while executing on short-term tactical plans.
	Be Flexible and Keep Learning
E	Need to be flexible and able to adapt to rapidly changing data and political conditions.
E	Currently I'm working to build my company the... I'm the President of the… and though I work as an executive. My question is that in this vernacular of an executive isn't it easy to lose sight of the big picture? Don't we need to stay connected to other companies to mentor and develop our skills or sharpen our abilities?
NE	Keep learning.
	Establish Respect
E	Establish respect of and from subordinates. Lead by example. Listen.
E	Respect everyone-Treat everyone Fair-Understand your environment- Make decisions--Communicate the organization vision and objectives
NE	Respect from others and for others should be added.

Appendix 8.2 (continued)

	Executive Roles
E	Key principle: build a common (project) vision then nurture collaboration, promote performance, cultivate learning and, last but not least, ensure results.
E	Transparent and team builder.
E	Proven experiences - there is no substitute for lessons over time
NE	Always have your radar on and be scanning the environment for change. Keep up with the news and how it will affect you and others around you. Keep a positive attitude and be flexible. Be a change master. If something negative takes place, deal with it as effectively as possible, (knowing you won't have all the answers) and try to remember that positive outcomes can arise from negative situations. People tend to bond and work together even more when the going gets tough. Stay focused and avoid gossip and talking about others when they are not present. Perform the best you can each day, knowing that each day will not always be your best. If you fall down, pick yourself up, dust yourself off, and get moving forward again as quickly as possible. Give back what was given to you.
NE	Make sure that the specific executive chosen is suitable for the specific executive role, e.g. a project/programme manager is a very different animal from a financial or a strategic executive.
NE	There are mid-level executive and top executive positions that would change answers based on emphasis. For example, top-level executives are more organizational, vision and big picture focused; mid-level executives are more immediate supervision and implementation focused.
NE	Listen to conflicting opinions with open mind; reassess internal bias.
NE	Requires high level of knowledge, dedication, proficiency and focus on a wide range of technical, political, organizational, and personal behaviors
NE	You need to understand the work and the mission - spaceflight hardware development is unlike any other, if you want to be effective, you have to have done it before.
NE	Understands systems in all dimensions, decisive, anticipatory
NE	Experience.... too many times "clones" are promoted to the executive level because they act and "behave" like their mentor. Management should not be "groomed" but earned through success at differing levels along the way. Give people opportunities to excel - those that excel should be promoted to the next challenge and tested again. When it is obvious that this individual can be challenged and has figured out a way to success then should they be elevated to an executive level. Too many of our "leaders" are promoted due to the old "its not what you know but who you know" method.
-	***Role of Technical Executive*** Thank you for asking! In my personal view, the role of technical executive leadership does include the items that have been brought up on this listing and it looks very promising to me. Although it may have been mentioned, the distinction between technical executive behaviors and executive behaviors in other disciplines may be the ability to understand what I like to call the artistic temperament of the technical contributor and then providing an environment of safety and sanity that maximizes the productivity of the individuals and groups. Executives of all types face chaotic environments, but I believe that technical executives must protect those whom they are charged to serve by creating what I like to refer to as a cone of sanity in the area of responsibility of the executive. In addition, they must be able to satisfy the curiosity of the technical contributors through the establishment of transparency (which I'm not sure that I saw mentioned directly) into the motivations and considerations of decisions made, visions crafted and directions taken by the executive. My belief is that through this trust can be established, which then increases performance. I believe that technical contributors do not demand that an executive agree with all of their opinions, but they do demand that there is a demonstration that the decisions made are based on some type of logic or rationale. In this way, in these environments, trust is earned through transparency and consistency of behavior that can be construed as rational.

Appendix 8.2 (continued)

	Advice for Executives
E	Need to establish clear lines of authority and accountability Roles and responsibilities need to be defined Delegate, know what you don't know Make decisions
E	Walk the talk Recognize your own mistakes; be human.
E	Be a good listener; be available for people to share. Don't be afraid to speak the "unspeakable", validate all assumptions. Keep the big picture in mind at all times. Make sure to have a clear message when articulating the big picture. Delegate, delegate, delegate.
E	Leading by example and always striving to do your best in all aspects of day-to-day career and personal life.
E	Be willing to take risks. Put the mission, project or organization ahead of your personal goals. Be willing to make decisions based on the information available and be willing to admit if you made the wrong decision and then change it.
E	Listen, collaborate, seek a mutual beneficial position, LEAD - make decisions. Experience - training & education cannot replace what is needed in experience (don't be afraid to make mistakes). COMMUNICATE
E	Act with integrity - treat others with respect. Articulate a vision, establish goals, and communicate the desired future state. Act decisively. Encourage open exchange of ideas.
NE	Keep things simple.
	Comments about Executives in NASA
E	It is important that subordinates do not undercut/sub-optimize the decisions of their superiors.
E	It is important to respect your superior. Unfortunately, some of the NASA executives need to be better at handling decisions.
NE	NASA organizations are not all the same in terms of culture; degree of delegation; roles, responsibilities, and accountabilities and therefore being effective can be context-specific. Also, this survey only implicitly addresses attacking organizational and cultural "stovepipes" or "silos" which is probably our number 1 stumbling block to greater effectiveness.
NE	Effective leaders require the support from the organization and Agency.
	Comments about the Survey
E	Q53 (Monitor the environment) is highly dependent on the context for its importance.
NE	You have an excellent list of executive behavioral attributes.
NE	Surprised that there was not a question on dealing with the politics of the agency and making sure it does not impede on the objectives of the agency.
NE	The designer of this survey clearly understands what it takes to effectively lead a NASA program or project
NE	Thank you for the opportunity to feedback. I responded as best as possible, as I do not have responsibility at the executive level. However, as a project manager there are several of the behaviors that I was able to address.

** E = comment made by an executive; NE = comment made by a non-executive.*

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